COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

l. 6, No. 7 JANUARY, 1935 25c a copy

Boiler Room at New York Hospital and Cornell Medical Center

Some Anomalies of Siliceous Matter in Boiler-Water Chemistry

Measuring Cinder Returned to Stoker Clinker Pit

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME SIX | NUMBER SEVEN

CONTENTS

FOR JANUARY 1935

FEATURE ARTICLES

EDITORIALS

DEPARTMENTS

H. STUART ACHESON, *General Representative* | **ALFRED D. BLAKE,** *Editor* | **THOMAS E. HANLEY,** *Circulation Manager*

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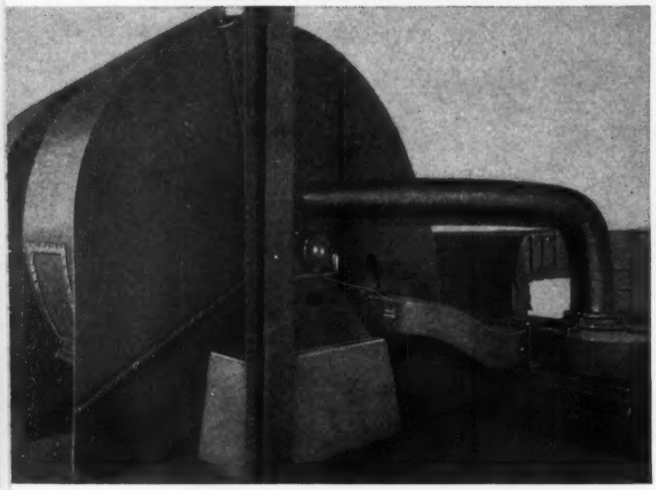
THESE LITTLE PIGS

WITH A SAVING



GURE 1—*Forward Curved Sirocco Induced Draft Fans with Sirocco Spiral Inlet Collectors (on the right) in the main plant of Wilson & Co., Chicago, Ill.*

GURE 2—*(below) Hydraulic Couplings which are used on the Forced and Induced Draft Fans and also on a 100 horsepower ammonia compressor.*

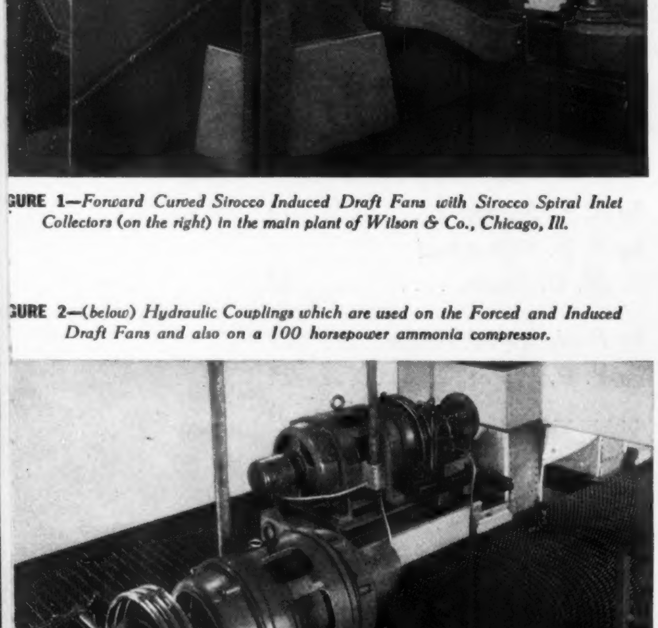


FIGURE 3—*(below) Showing the Inlet Vanes of the Sirocco Spiral Inlet Collector used on the Wilson & Co. plant.*

ALMOST as old as the Mother Goose rhymes is the packing industry's reputation for low distribution, sales and marketing costs. So unbelievably small is the packers' percentage of the dollars spent for meat that no one outside the industry, and comparatively few packers themselves, had figured further savings possible.

Yet competent, capable engineers, Allen McKenzie, J. M. Lenone and P. L. McGehee of Wilson & Company, with a background of years of experience, visioned even greater efficiency for the industry that has always been known as one of America's most efficient.

Well they knew the small percentage of the dollar the packer works on and they were thoroughly familiar with the parts of pennies per pound spent for power. Yet they made their attack in the power plant, figuring that what was economical and efficient operation over a period of years might possibly offer a means of further economy and further efficiency under present operating conditions with modern machinery and equipment.

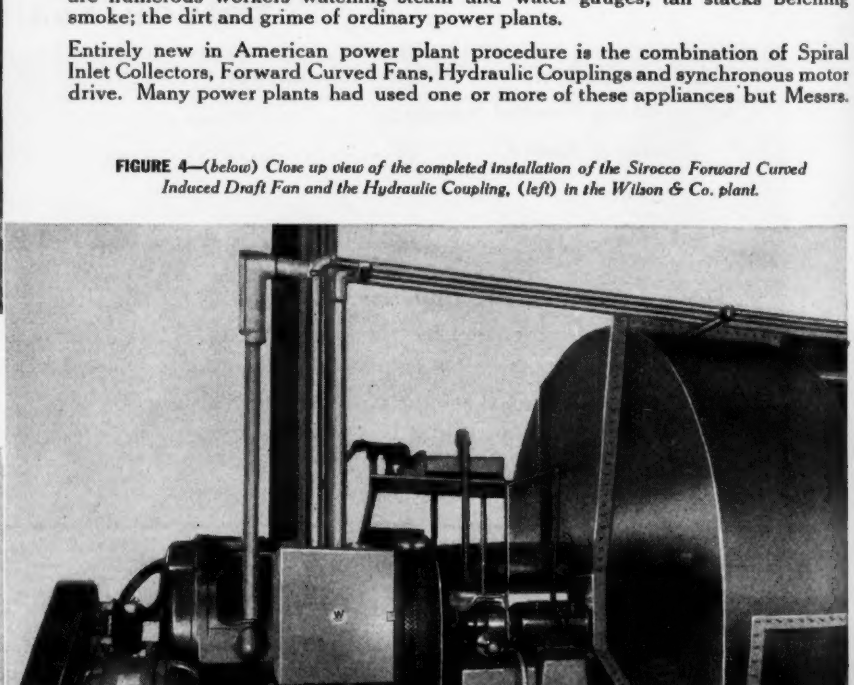
The result of their work is the new, complete, compact power plant of Wilson & Company, Chicago. This plant not alone typifies all that is modern in engineering methods and procedure, but is one that, conservatively estimated, is capable of saving upwards of $100,000 annually.

Approximately 18,000 tons of coal will be saved yearly, although the same amount of process steam as was formerly used will be generated, as well as all electrical energy. Processing and manufacturing departments have been speeded up. More power than needed for 100% increased operation can be made.

There is no shoveling of coal nor raking out of ashes. Conspicuous by their absence are numerous workers watching steam and water gauges; tall stacks belching smoke; the dirt and grime of ordinary power plants.

Entirely new in American power plant procedure is the combination of Spiral Inlet Collectors, Forward Curved Fans, Hydraulic Couplings and synchronous motor drive. Many power plants had used one or more of these appliances but Messrs.

FIGURE 4—*(below) Close up view of the completed installation of the Sirocco Forward Curved Induced Draft Fan and the Hydraulic Coupling, (left) in the Wilson & Co. plant.*



Went to Market

OF $100,000 YEARLY

McKenzie, Lenone and McGehee in their scheme of things selected all four to make the packers' exceedingly small part of the dollar go farther.

The Hydraulic Coupling (see figures 2 and 4) is a simple, efficient means of driving a machine at an infinite number of speeds with a constant speed driver. Its characteristics are such that it is particularly adaptable to machines whose power varies as to the cube of the speed, such as pumps or induced and forced draft fans similar to the ones used in the Wilson & Company plant. The Hydraulic Coupling makes it possible to combine the electrical advantages of constant speed induction or synchronous motor drive with the numerous operating advantages of variable speed drive.

The application of the Hydraulic Coupling in the Wilson & Company plant eliminates damper controls and electric motor control equipment and makes possible a minute automatic adjustment of speed. It also greatly reduces erosion and effects power savings of substantial size. (See figures 2 and 4.)

The Sirocco Spiral Inlet Collectors (see figures 1, 3, and 5) have a distinct and decided advantage and are fittingly placed in this model power plant to minimize the fly ash nuisance and further to prevent erosion. Their ability to perform effectively in small space with a minimum of care and attention over a long period of years means a saving of valuable space and long life to complementary equipment.

Forward Curved Sirocco Induced Draft Fans further add to the efficiency factor of this plant. The Sirocco fan wheel inherently affords more sensitive response to speed changes than other types and the low tip speed characteristic of the Sirocco Fan insures long life and further minimizes erosion and the results of erosion. The Sirocco Fan operates at the lowest tip speed of any fan on the market. High Speed Fans, Hydraulic Couplings and synchronous motors furnish air for forced draft.

The maximum advantages of power factor correction through synchronous motors on both forced draft fans and induced draft fans is permitted by the use of Hydraulic Couplings. The advantages and economies of the one are made possible by the use of the other, all to the benefit and profit of the packers' small part of the dollar.

Hydraulic Couplings are also used in the Wilson & Company power plant for furnishing variable speed drive to a 100 h. p. ammonia compressor.

Much has been said of the capabilities of the men and equipment responsible for this new power plant—much more will be said of the efficiency and skill of the packing industry as exemplified by Wilson & Company. But perhaps you have a similar opportunity to profit—to stretch your part of a dollar.

The American Blower Corporation, with more than 50 years' experience in air handling—air conditioning, mechanical draft, dust collection, heating, ventilating, air washing and cooling equipment—is always ready to consult with interested engineers with regard to increasing plant efficiency and economy or improving operating conditions. There is no obligation. American Blower offices in charge of competent engineers are located in all principal cities.

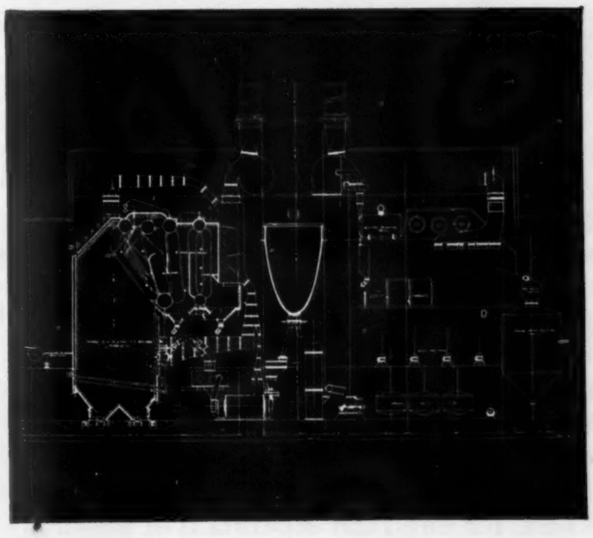
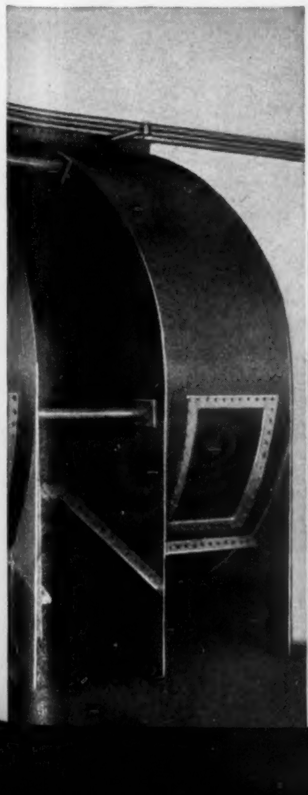


FIGURE 6—*(at right) Longitudinal section of Wilson & Co.'s new boiler room.*



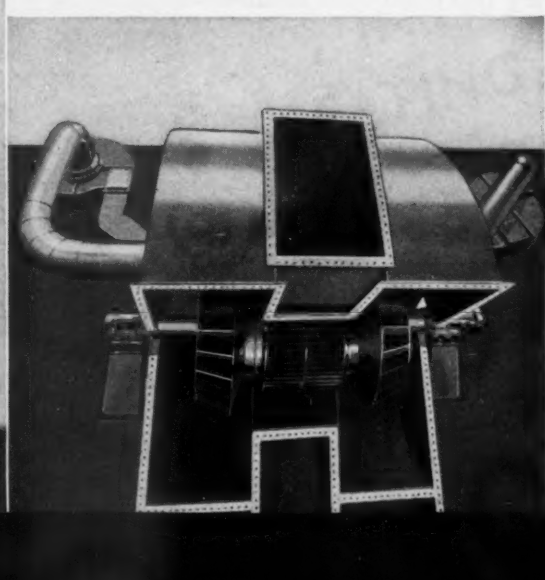


FIGURE 5—*(below) Bird's-eye view of the Sirocco Forward Curved Induced Draft Fan coupled with the Sirocco Spiral Inlet Collector (Showing collectors in background, also see FIGURE 3)*

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Publisher's Announcement

This issue of *Combustion* inaugurates a new policy with regard to the distribution of advertising and editorial matter. It will be noted that sufficient advertising is interspersed with text matter so that the principal articles may be clipped and filed without interfering with any other article. We believe this arrangement will be decidedly advantageous to our many readers who have found *Combustion* to be the source of much material of permanent reference value.

Several years ago, at the suggestion of readers, we adopted the policy of eliminating article carry-overs, in the case of articles that do not completely fill the last page, by including thereon news and miscellaneous matter which there would be no occasion to file. This arrangement was a definite improvement but was not a complete solution in that articles ending on a right page necessarily had to include the first page of the following article which some might wish to file under a different classification. Recent letters from readers have again brought this subject to the fore. The arrangement adopted in this issue corrects this deficiency and also permits a more desirable distribution of advertising which will be beneficial to advertisers as well as to readers.

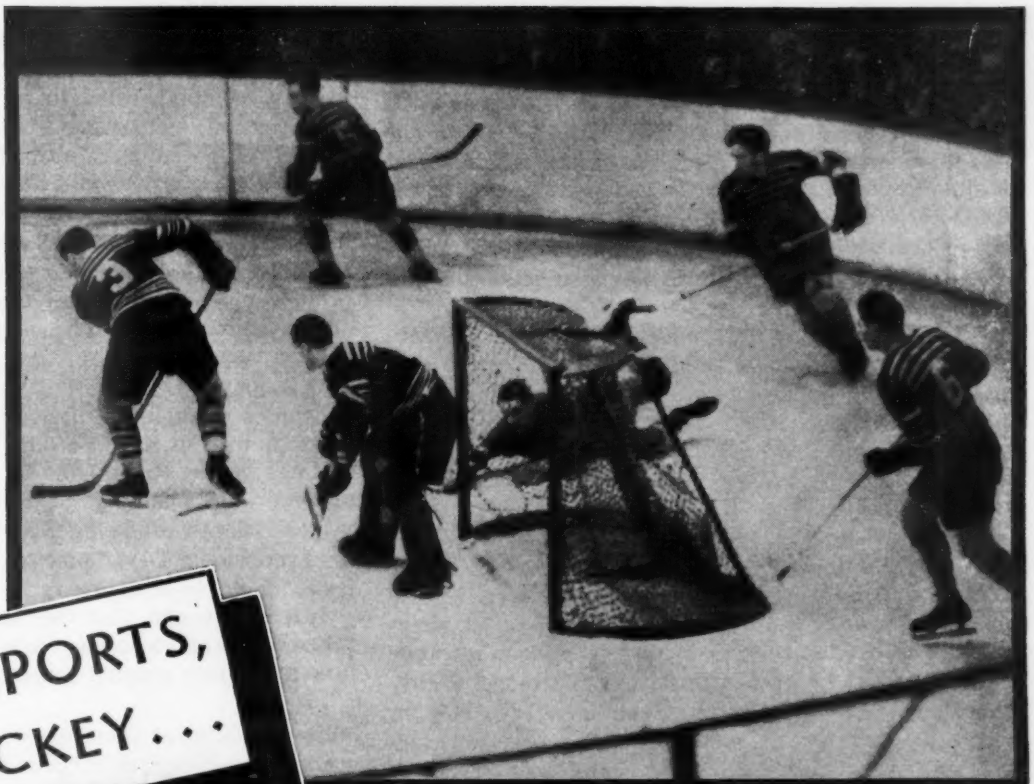
In adopting this plan we are departing from a more or less traditional practice in the publishing of trade and technical periodicals, which seems to have regarded advertising and editorial pages as so many sheep and goats requiring positive separation. *Combustion* does not agree with this viewpoint since it considers its advertising pages as valuable supplementary matter to its text. In the latter, trends, practices, new developments and operating results are presented and discussed as clearly and competently as our abilities permit. In the former are presented details of specific equipment which reflect these trends and practices and accomplish these results. One is essential to the other, and together they make the picture complete. Since in all publications they are included within the same covers, we see no need for any rigid separation of them.

A number of general publications and some business and technical periodicals have now adopted similar make-up, and we are glad to join this group in what we regard as a progressive step calculated to improve *Combustion's* service to its field. Some of our readers may at first find it a little strange, but we are confident that after they have become familiar with it they will commend it.

Charles McDonough

Vice-President

Action!



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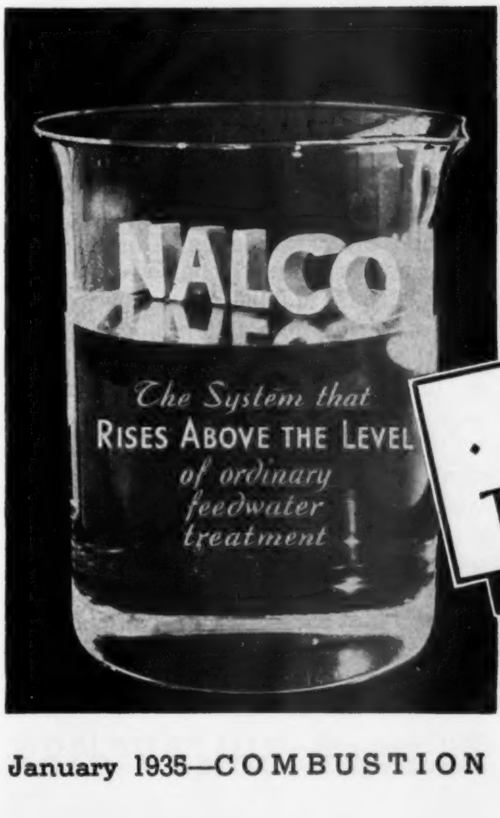

. . . IN WATER TREATING, IT'S

NALCO

EDITORIAL

Preheated Air and Stoker Maintenance

For some years opinion has been divided as to the most economical range of preheated air temperatures for stoker operation. With the general adoption of the reheat cycle and the consequent more extensive use of heat recovery surface in the form of air heaters, the selection of preheat temperatures has assumed wider importance.

Under favorable load conditions and with certain coals, temperatures of 400 to 500 F, or higher, have been employed with apparent satisfaction in a few cases, whereas others who have attempted to employ such temperatures have found the resulting stoker maintenance prohibitive. More conservative practice has favored a limit of 300 to 325 F.

However, opinions based on individual experience are of little value unless all the variable factors are weighed and unless, collectively, they indicate definite limitations and trends. In collecting data from thirty-three operating companies, covering experience with one hundred and twenty-two underfeed stokers using preheated air, Messrs. Dillon and Engle have been able to present a valuable cross-section of experience and practice. Moreover, they have reduced the data to a common basis for comparison of stoker maintenance by correcting for such variables as stoker area, coal burned per square foot per hour and ash in the coal. Maintenance cost as high as thirty cents per ton was found with 500 F air whereas the average for 250 F to 350 F was found to lie between five and ten cents per ton, which bears out the more conservative opinion.

The paper is especially valuable to power plant designers in that it provides a definite indication of underfeed stoker maintenance for given conditions, in the place of estimates and unsupported speculation.

A Much Needed Survey

To what extent are engineers gainfully employed? Have they been harder hit by the depression than men in other professions? How has their earning power changed during the last few years? How many, by force of circumstances, are now engaged in non-engineering work? Finally, to what extent does the supply exceed the demand and what industries or lines of endeavor offer possibilities, heretofore neglected, for men with engineering training?

These are moot questions some of which should find answers in the survey now being made by the U. S. Bureau of Labor Statistics in cooperation with the American Engineering Council.

Numerous studies have been made from time to time by various groups with a view to securing information on the material status of engineers, but none has been sufficiently comprehensive to give an accurate picture of the situation. Many reports and papers have been delivered on the subject and discussion has been rife, but personal observations and insufficient data have characterized many of these well meant efforts. On the other hand, the present survey, covering approximately one-third those listed as engineers in the last Census, should provide much concrete information and afford a fairly accurate cross-section of conditions in the engineering field as they exist today.

It is doubtful if the data collected will be of immediate assistance to engineers individually, or until the capital goods industries have become normally active, but the findings should be valuable to the profession as a whole in long range planning, especially in supplementing the very excellent work being done by the Engineers' Council for Professional Development toward clarifying the professional status of engineers.

It is unfortunate that the Survey had not been undertaken a year and a half ago in which case engineers might now have been reaping some benefits.

Looking Ahead

With the beginning of each new year it has long been customary in most lines to take stock of progress during the preceding twelve months, not with the idea of setting up post mortems, but with a view to discovering what may be ahead. While 1934 was not particularly active in the steam plant field, compared with some previous years, it was not devoid of progress and some very important installations. These are reviewed by Doctor Hirshfeld elsewhere in this issue.

In no previous period has the subject of power been so widely discussed. Despite the controversial nature of these discussions, brought about by the Government entering the field and the agitation for reduced rates, the net result has been to make the public power-minded. This ultimately should result in much greater use of electricity. Evidence of this is found in the rapidly increasing central station load, the peak of which is not far behind that of 1929. It is also causing industrial managements to pay closer attention to their power problems, which is reflected in the numerous replacements of obsolete equipment, the notable increase in stoker sales and in many plans now being made which involve higher steam pressures, more efficient use of steam in process and more economical firing of fuel.

With business receiving an even break in 1935, and provided no unforeseen obstacles arise, it is reasonable to assume that these and many more such plans will fructify to the end that the present year will be an active one in the power field.

Steam Turbine Developments in 1934

Relatively few large turbines were built in this country during the past year, the greatest activity being in units for industrial plant service employing high back pressures. The indicated trend is toward modernization of existing stations by superimposing high-pressure boilers and turbines on present low-pressure systems. Reheating is becoming less popular. Some special turbine-generators were built, notably to supply high-frequency current in the rayon industry and very high speed units for blowers. Particular attention is being paid to minimizing oil-fire hazards and research has been directed toward improving blade efficiency.

WHILE few large or spectacular turbine-generators were built in this country during the past year, the modernization of existing stations by the addition of high-pressure boilers and turbines, arranged to operate in connection with existing equipment, has resulted in a number of interesting installations. Research and development have dealt particularly with improvements in efficiency through refinements in the blade path and with means for insuring increased safety from fire.

Reviewing the situation for the Westinghouse Electric & Mfg. Company, A. D. Hunt, Manager of its Engineering Department, observes that improvements in blade efficiency are due largely to the development of rapid and satisfactory means for investigating the actual behavior of the steam in its passage through the blade rows. At the same time practical immunity to blade failure has been more closely approached as a result of the introduction of testing devices capable of making determinative tests in a fraction of the time required by methods heretofore employed.

Important among these devices is an electro-magnetic vibrator, Fig. 1, which has greatly facilitated the practical determination of natural frequencies and modes of vibration of the blades. The device comprises a vibrator, a d-c coil movable in an a-c field and capable of being attached by a spindle to the object to be vibrated; also a tuning and amplifier unit capable of determining the frequency of vibration at any value between 30 and 10,000 cycles. The amplifier has a maximum output of 500 watts, so that the energy input may be adjusted to cause failure of a specimen within a reasonably short time.

Another of these devices records visually and photographically the vibrations in blades mounted on a rotating disk and subjected to forced vibrations of known intensity. This is a close approach to a determination of the actual vibratory behavior of a blade or group of blades mounted in a turbine and rotating at operating speed.

In large condensing turbines one of the important problems of design has to do with the exceedingly large steam passages required in the last two or three rows of stationary blading. An improvement in both the efficiency and in the mechanical structure of these rows has been obtained by making the vanes of stainless steel and casting them into shrouds and bases of cast iron.

Fig. 1—Electro-magnetic blade vibrator with group of low-pressure blades set up for test

As a result of extensive research into the flow conditions in exhaust passages carried out by means of models operated with air as the fluid medium, important progress has been made in the reduction to a minimum of the loss due to the pressure drop between the exhaust annulus and the condenser tube surface. Furthermore, the effect of obstructions, such as stays, has been evaluated and the limits of usefulness of deflectors, etc., have been determined and the pressure distribution over the exhaust area plotted, so that by co-relating the design of exhaust chamber and condenser maximum efficiency may be obtained.

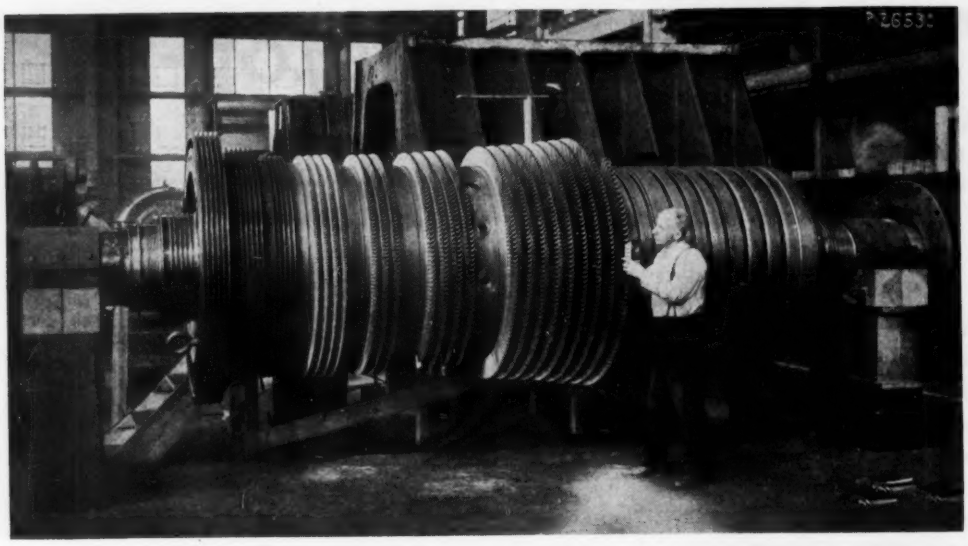

Fig. 2—High-pressure rotor of 165, 000-kw tandem-compound turbine for the Richmond Station in Philadelphia

Among the more important Westinghouse turbines installed or put in operation during the past year was an 18,000-kw, 650-lb, 825 F machine replacing an earlier machine of the same capacity which was destroyed by fire in the Burlington Station in 1933. This machine serves as the high-pressure element of a cross-compound unit, the low-pressure elements of which are 10,000-kw, 200-lb machines. The addition of the high-pressure unit has increased the station capacity nearly 50 per cent and reduced the station heat rate about 40 per cent.

Another turbine unit of more than ordinary interest is the 165,000-kw, two-cylinder, tandem-compound machine now being erected at the Richmond Station in Philadelphia. The steam conditions are 375 lb gage 825 F total steam temperature and a vacuum of 29 in. The high-pressure element of this unit (see Fig. 2) is of the single-flow straight reaction type with a cast-steel cylinder base and cover, each made in two pieces, and with a rotor made up of a chrome molybdenum steel forging at the high-pressure end and a low-pressure end of forged carbon steel. The low-pressure element is of double-flow construction and the rotor consists of ten shrunk-on disks of chrome-molybdenum steel mounted on a carbon-steel shaft. All the blading is of the reaction type, the first four groups of the high-pressure element being of the axial clearance type. The last three rows of rotating blades at each end of the low-pressure spindle are of the serrated root side-entry type and the last three stationary rows at each end consist of groups of stainless steel blades cast into cast-iron bases and shrouds (see Fig 3).

Both the Richmond and the Burlington turbines have been designed in the light of recent developments in control and fire protection. Oil is used as the lubricant, while the operating fluid for the valve mechanisms is "aroclor," a non-inflammable fluid, consisting of an organic compound of diphenyl and chlorine. The machines depend for their governing upon the variations in pressure at the periphery of an impeller on the turbine shaft through which oil, metered from the main oil-pump discharge by an orifice, is forced in the reverse direction and discharges to a drain. These pressure variations are communicated to a pressure transformer in which the impulses received in the oil stream are used to control the aroclor, in which the original impulses are magnified about ten times. The Burlington turbine, being a base-load unit, has only two governor-controlled valves, whereas the Richmond turbine has seven. All are hydraulically operated with aroclor.

An addition to the separation of the lubricating and

Fig. 3—Low-pressure stationary blade groups for 165,000-kw unit. Groups of stainless steel blades are cast into cast-iron bases and shrouds

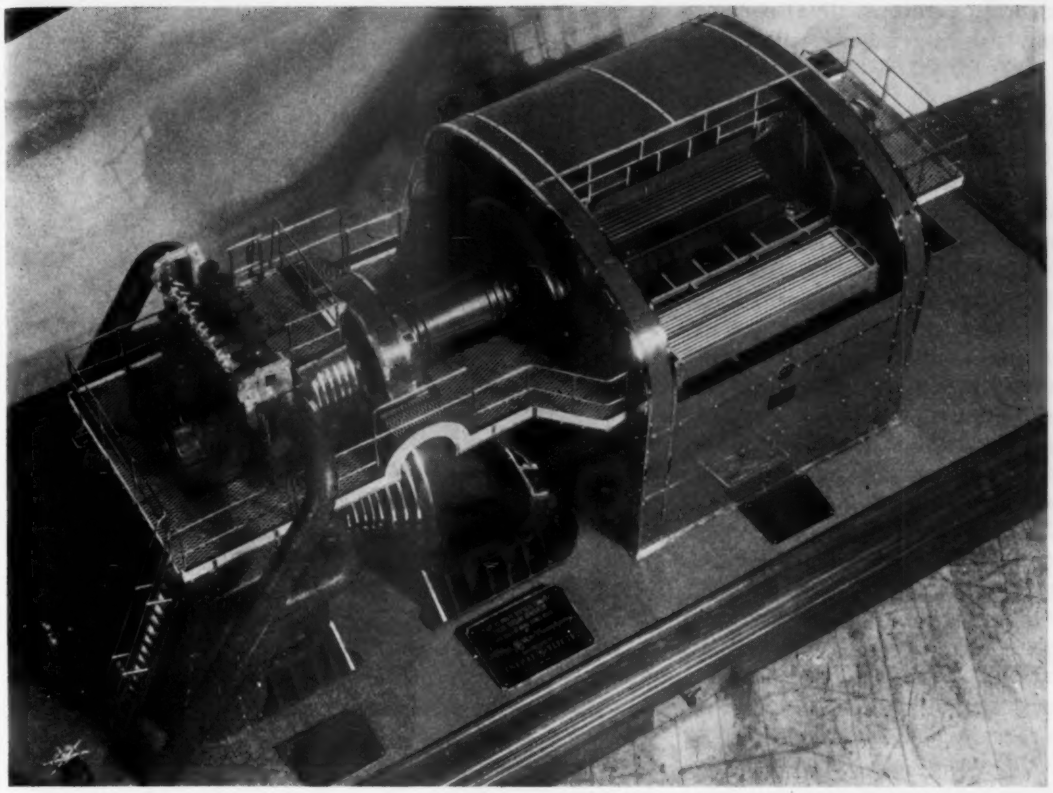

Fig. 4—Model of Ford 110,000-kw high-pressure, high-temperature turbine of the vertical compound type

operating systems, the oil-fire hazard has been further reduced by the use of seamless steel piping, elimination of flanged joints wherever possible, supporting pipes so as to minimize stresses and vibration, reducing the size of oil reservoirs and housing them in a separate enclosed fireproof room, and covering hot steam pipes in proximity to oil pipes with sheet metal jackets to direct any oil spray away from the hot parts.

Water catchers, in the form of grooves, to entrain some of the moisture in the steam are located before the last two rows of stationary blading in the Richmond turbine. The lowest pressure water catcher drains to the condenser, but the drain from the higher pressure water catcher is bled to a feedwater heater. The extraction of this moisture tends to reduce blade erosion and also improves the thermal efficiency of the unit because of the heat being regained in the feedwater.

The General Electric Company reports that work has been started on the second 110,000-kw turbine-generator of the vertical-compound type for the Ford Motor Company. This unit is designed for 1200 lb and 900 F, instead of 725 F as was the earlier unit, thereby avoiding the complication and additional expense of reheating the steam between the high- and the low-pressure units. Savings in space and foundation costs are realized by mounting the high-pressure unit on top of the low-pres-

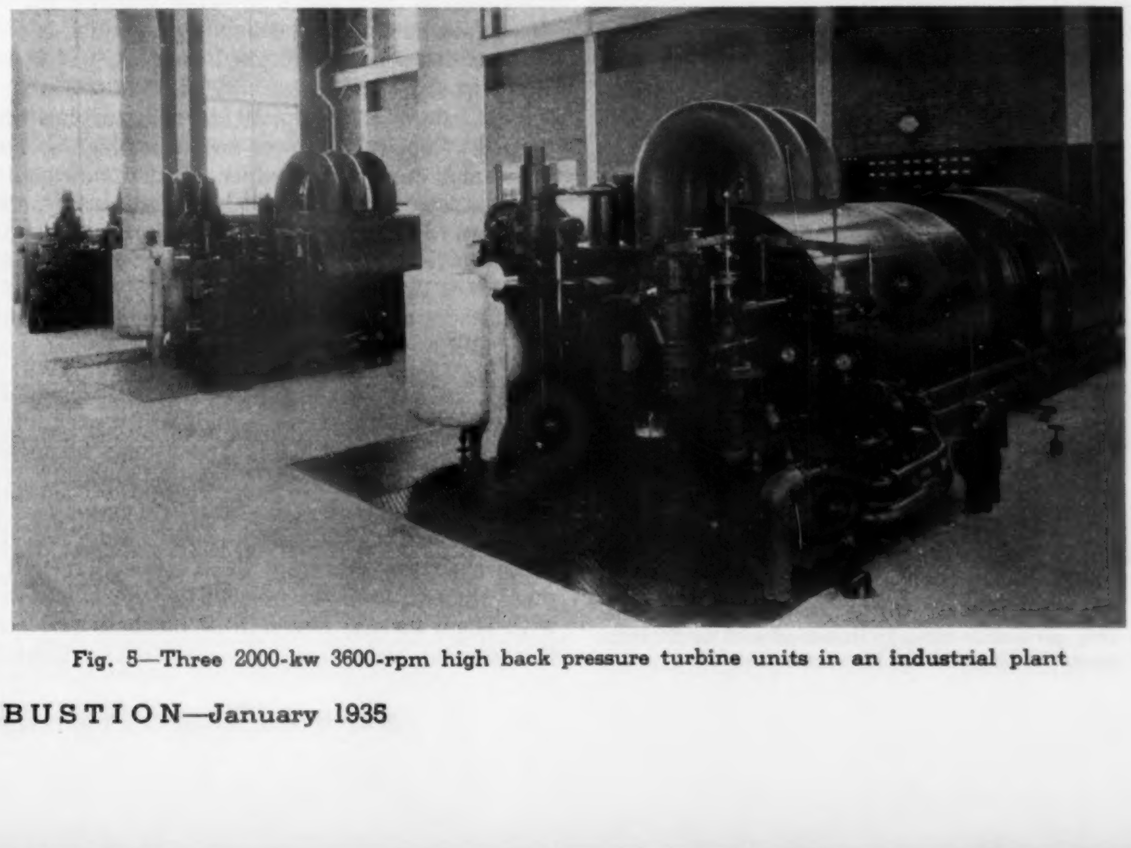

Fig. 5—Three 2000-kw 3600-rpm high back pressure turbine units in an industrial plant

sure unit, both of which will operate at 1800 rpm. A 15,000-kw non-condensing turbine-generator will also be installed to operate at 1200 lb, 900 F and exhaust to process at 250 lb.

Another high-pressure machine is that recently installed at the plant of the Firestone Tire & Rubber Co., Akron, O. This is a 10,000-kw, 1200-lb, 750 F non-condensing turbine-generator which exhausts to evaporators which, in turn, supply steam to process.

The Detroit Edison Company is carrying on a modernizing program at its Connors Creek Station in which five old turbine-generators, designed for 200 lb and 550 F are being rebuilt into three new units to operate at 600 lb and 825 F. The rebuilt units will provide a station heat rate approximately 25 per cent better than before

A number of turbine-generators have been installed by the rayon industries to generate current at frequencies up to 180 cycles. The smaller machines employ four-pole generators operating at 5400 rpm and the larger ones six-pole generators at 3600 rpm. Two 2350-kw six-pole units are being built for 180 cycles. The turbines for driving these high-frequency generators are designed for good efficiency at any frequency between 120 and 180 cycles.

Asked for a statement on trends in turbine practice, J. Wilson, Engineer of the Steam Turbine Department of the Allis-Chalmers Mfg. Co, states that during the past year there has been an increasing demand for industrial turbines exhausting at high back pressure and to meet this demand his company has designed a line of high back pressure turbines.

In a number of fields, such as the oil industry, steam at relatively high pressure is necessary for process work and turbines designed to exhaust at pressures of 150 to 200 lb gage have been designed to operate at inlet pressures of 400 to 600 lb and steam temperatures up to 750 F. Three such turbines are shown in Fig 5. These are 2000 kw machines operating at 3600 rpm and high back pressure. A feature of these machines is the symmetrical construction of the cylinders to eliminate heat distortion.

Another field for such units has been found in the modernization of old power plants where full advantage can be taken of the increased economy of higher steam pressures at minimum expenditure, by the installation of

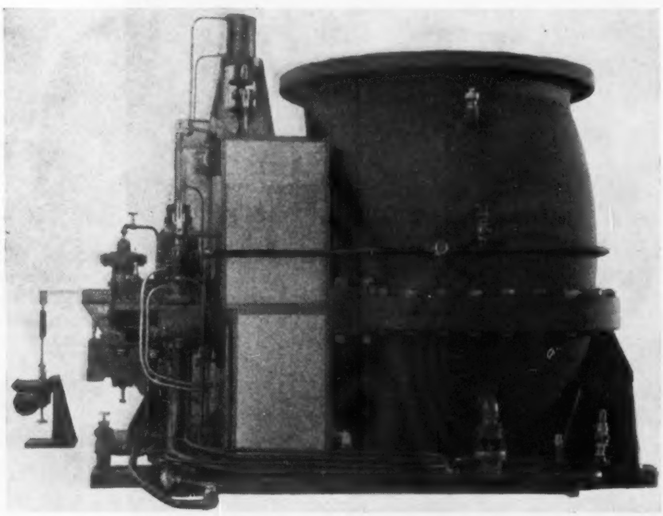

Fig. 6—A 1250-kw low-pressure turbine built to fit on the bed plate of a generator already installed and to fit into the layout of the existing low-pressure piping

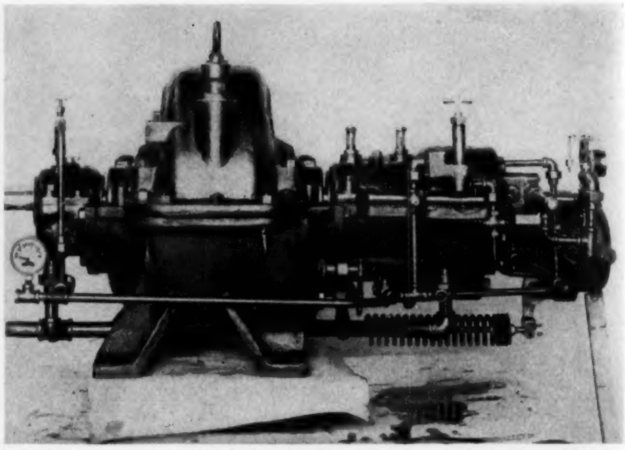

Fig. 7—A 150-hp, 10,000-rpm turbine developed for blower and other high-speed drives

high-pressure boilers and high back pressure turbines exhausting into the existing steam lines.

The fire hazard, on account of higher steam temperatures now commonly used, has figured prominently in recent designs. To reduce this hazard the Allis-Chalmers Company has designed its later units so that all of the lubricating system, including the regulating mechanism, is on the opposite side of the unit from the valves and high-temperature parts. The connection between the oil relay system and the valves is mechanical.

This company is also installing an 80,000-kw, 1200-lb, 850 F turbine at the Port Washington Station of the Milwaukee Electric Railway & Light Company. This unit will be supplied with steam from a single boiler.

In the field of small and medium-sized turbines the Moore Steam Turbine Corporation, according to G. R. Probst, of that company, reports that these units have now been developed to the point where they have practically all the refinements of large units and automatic control is being furnished in increasing numbers.

Fig. 6 shows a 1250-kw low-pressure turbine built to drive an existing generator on the original bedplate. The steam chest had to be arranged so that it could be connected to the existing low-pressure piping without changing its layout. It has a governor which holds the pressure in the exhaust line constant and which is adjustable so as to maintain the desired pressure. It operates on steam from 1 to 10 lb gage and exhausts at 28 in. vacuum.

Fig. 7 shows a 150-hp, 10,000-rpm turbine which has been developed for blower and other high-speed drives. This small turbine is complete with its own lubrication system, a variable-speed hydraulic governor and a hand oil pump for starting.

The Worthington Company, Incorporated has recently established a Pacific Coast regional headquarters at Los Angeles, which will center jurisdiction and development of the Corporation's business in the West now included in the coverage of the Worthington district offices in Seattle, San Francisco, Los Angeles and El Paso. This headquarters, under the direction of an executive officer of the Corporation, will supplement the efforts of the present district offices and unite with them for the dispatch of business and service to the growing volume of business in the West.

Progress in Steam Power

As Reviewed by C. F. Hirshfeld*

THERE have been no revolutionary developments in the field of steam power. On the other hand, there has been a continuing evolution toward the common acceptance of high steam pressures and high steam temperatures. Steam pressures up to about 1400 lb may now be considered as normal instead of partly experimental, both with respect to industrial and to public utility plants. The steam temperature has been stepped up more or less rapidly from the region of 700 F to something of the order of 850 F. Higher temperatures are to be expected as experience is gained and as the necessary alloys become available at sufficiently low prices. It is significant that at least one manufacturer expresses willingness to construct a 200,000-kw turbine to operate with an initial steam pressure of 1200 lb and a steam temperature of 1000 F. The unit would be of the tandem type and would operate without reheat.

The ability to utilize high steam temperatures is gradually but certainly bringing about the common use of installations in which high steam pressures are used without reheating, thus producing a reduction in complication and first cost. In fact, it seems as though the arrangement now most favored for highly efficient steam stations may be described simply as the use of the highest steam pressure that can be utilized safely without reheating and with the highest steam temperature that the designer believes proper for the given conditions of use. At present, commercial installations are generally limited to steam temperatures between 800 and 900 F, with steam pressures in the range from, say 600 up to 800 lb. The use of 1400 lb steam with an initial temperature of 900 F on a 110,000-kw unit as ordered for the River Rouge Plant of The Ford Motor Company and to be operated without reheat in spite of an expected vacuum of the order of 1 in. Hg. indicates how far the turbine manufacturer is willing to go in the elimination of reheat. However, the recent installation of at least one major reheating plant at 1400 lb should be recorded.

It should be noted that one of the essentials for satisfactory operation at high initial temperatures is a very constant steam temperature. Much ingenuity has been displayed by designers and manufacturers in producing equipment that will achieve this result.

The availability of equipment which will permit the use of high pressures and temperatures without reheating is having a very noticeable effect upon the rehabilitation of existing steam plants. The super-position of high-pressure and high-temperature equipment exhausting into the older equipment permits the increase of capacity of old stations and a measurable increase of overall net thermal efficiency while salvaging much of the existing investment. It appears as though this method will be used extensively in the near future.

Great improvements have been made in the conditioning of feed and boiler water for operation at high pressures. Such conditioning is a matter that should not be overlooked in planning any high-pressure installations.

Trends in Boiler Practice

A tendency in boiler design which has been noticeable for several years, namely the use of completely water-cooled furnace walls, small boiler heating surface and large heat recovery surface in economizers and air preheaters, continues. Also, the use of welded construction for drums, headers and other parts is making very rapid progress. A very notable accomplishment in this direction is the drum for a boiler ordered by Firestone Tire and Rubber Company. This unit is to produce 300,000 lb of steam per hour at a pressure of 1400 lb. The drum is welded throughout. It is 4 in. thick, has a length of 23 ft and an inside diameter of 54 in.

The announcement by Westinghouse Electric & Manufacturing Company of the rights for the development of the Benson type boiler plant in this country marks another stepping stone in the high-pressure field. This boiler was developed for use at or above the critical pressure but it is reported to have been used in practice below that pressure with good results. One of the latest proposals is a unit of boiler and turbine with the output of the turbine controlled by variation of the boiler pressure. This opens up what may prove to be a fruitful field.

The Loeffler type of boiler in which evaporation is produced in an unfired vessel by means of highly superheated steam is gradually finding acceptance in Europe. No installations have been made in this country. A recently reported authoritative test of such a boiler in Europe indicates an acceptable thermal performance. Very little factual information is available regarding maintenance and possible operating difficulties.

Fuel Burning Equipment

Fuel firing equipment has made slow advances along lines indicated during the past few years. The notable development in underfeed stokers is the successful use of zone control of air supply in several large stoker installations. Although this practice started several years ago, it spread very slowly because of initial difficulties and because of the increased complication. It may now be said to be an established arrangement.

A new control unit has been developed for hydraulically operated underfeed stokers which automatically reverses the movement of the ram in case the forward progress of the latter is impeded by an obstruction.

In the field of pulverized fuel firing there appears to be a very definite swing toward unit mills as against the central preparation and storage system. There also appears to be an increasing tendency toward the use of the slagging type or slag-tap type of furnace. A move-

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* From a general report on Progress in Power, presented at the recent Annual Meeting of the American Society of Mechanical Engineers. Mr. Hirshfeld is Chief of Research, The Detroit Edison Company.

ment toward larger fuel capacity per burner has been obvious for years. The latest achievement is a burner at the West Virginia Pulp and Paper Company which burns sufficient coal to produce 135,000 lb of steam per hour, representing a heat liberation of about 205,000,000 Btu per hr.

An interesting and undoubtedly valuable development is an arrangement by means of which coal pulverizers can supply pulverized fuel satisfactorily at very low ratings, as for example during week-ends, lunch hours, etc. In this arrangement more than the required amount of fuel is taken from the mill; that required to carry the existing load is taken to the burner and the surplus is returned by a bypass to the pulverizers.

Metallurgical Improvements

Advances in methods and equipment for power generation are in many respects intimately tied to advances in metallurgy. This is particularly true at the present time because of the efforts to use higher temperatures, higher pressures and higher speeds while at the same time reducing cost of maintenance or, at least, not increasing it.

The advent of stainless steel and of numerous other alloy steels has contributed greatly to the improvement of power generation equipment; hydraulic, internal combustion and steam. Much remains to be done but the rate of progress is now high and new developments may be expected frequently.

One rather astounding metallurgical accomplishment is the production of heat treated alloy cast iron which has remarkable properties not commonly associated with cast iron. The fact that such material is being used successfully for the crankshafts of automobile and high-speed diesel engines indicates in a striking way the astounding results that flow from the efforts of modern research.

Welding

Reference has been made to the fusion-welded drum of a high-pressure boiler purchased recently. In spite of the short time that has elapsed since provision for such fabrication was included in the Boiler Code, it is now standard practice in the industry. Tremendous advances have been made in both welding methods and means for checking the completed welds.

Concurrently, there has been a rapid increase in the use of welded joints in steam lines and in other pressure carrying parts. One notable development in this connection is an electrically heated annealing equipment adapted to anneal welded pipe joints in place. Welding is also coming rapidly to the fore in the construction of many parts of prime movers of all sorts.

Alex D. Bailey, superintendent of generating stations and assistant to the chief operating engineer of the Commonwealth Edison Company, has been promoted to the position of assistant chief operating engineer. **A. E. Grunert**, formerly efficiency engineer of generating stations, succeeds Mr. Bailey as superintendent of generating stations.

C. E. Davies Becomes Secretary of A.S.M.E.

C. E. Davies, since 1931 Executive Secretary of The American Society of Mechanical Engineers, was appointed national Secretary of that Society at a meeting of its Council on December 7, 1934. Mr. Davies has been a member of the staff of the Society since 1920. He succeeds Dr. Calvin W. Rice, whose sudden death in October of this year terminated twenty-seven years of active service.

Mr. Davies was born in Utica, New York, and received his early education at the Utica Free Academy, from which he was graduated in 1907. After an interval of three years he entered Rensselaer Polytechnic Institute, Troy, N. Y. Here he was elected to the honor societies of Tau Beta Pi and Sigma Xi.

Following graduation from Rensselaer Polytechnic Institute, in 1914 with the degree of Mechanical Engineer, Mr. Davies began his professional career in the production department of the Smith Premier Works, Syracuse, N. Y. of the Remington Typewriter Company. Here he came in contact with Henry L. Gantt, one of the pioneers in industrial management.

During the War, as first lieutenant and later as captain, Mr. Davies served in the Ordnance Department, U. S. Army, being assigned to the Frankford Arsenal, where he was responsible for developing methods of manufacture and production control schemes for the manufacture of artillery ammunition, and later for the operation of the fuse shop at that arsenal. Since the War he has maintained active contact with the Ordnance Reserve of the U. S. Army and at present holds the rank of Lieutenant Colonel in the Ordnance Reserve Corps in the New York District.

At the close of the War, Mr. Davies returned to the Remington Typewriter Company, which he left in March 1920, to take up the duties of associate editor of The American Society of Mechanical Engineers. In 1921 he became managing editor and assistant secretary of the Society. Under his supervision were the activities of numerous society administrative committees responsible for the meetings and publications of the Society. In 1925 he was placed in charge of the administration of the headquarters office and in 1931 was appointed Executive Secretary.

Mr. Davies' ability as an organizer and executive has also made him prominent in the affairs of other organizations. He is a fellow of the American Association for the Advancement of Science, a member of the Institute of Management, the American Management Association, American Association for Adult Education, Reserve Officers Association, the Army Ordnance Association, the Engineers' Club, New York, and the Cosmos Club of Washington, D. C.

Some Anomalies of Siliceous Matter in Boiler-Water Chemistry

The author discusses several apparently divergent views of certain authorities concerning theories of siliceous scale prevention. He points out that hardness is not an index of the tendency of siliceous water to incrust boilers, that the use of evaporators does not insure the complete elimination of such matter and that higher pH values are desirable with high silicate content of boiler water; furthermore increased rate of blow down usually results in increased rate of scale accumulation under such conditions.

By R. E. SUMMERS

Asst. Professor of Mechanical Engineering Oregon State College Corvallis, Oregon.

SILICON, the second most abundant element of the earth, is found in perhaps every natural water. That element, through its multiform compounds, is a not inappreciable impurity of all boiler feedwaters. Under certain circumstances the compounds of silicon are obvious major contributors to the inorganic concentrations within steam boilers usually responsible for scale formation, for large blow down and for associated boiler ills. In other circumstances those materials exact the same toll of boiler operation, while conceded the role of inert or inconsiderable feedwater impurities. The universal appearance of silicon compounds in water (*1*)[1] is capable of certification by any persons who will look inquiringly into geochemical data. The bringing of silicates into aqueous solution is anticipated both from energy relations of chemistry and from many logical stoichiometric equations involving silicon-bearing rocks of frequent occurrence. In some regions of this country (*2*, *3*) attention to the action of silicon compounds is of certainty thrust to the fore in boiler-water chemistry.

It is the anomalous position of siliceous material that now commands general attention in the treatment of boiler water and boiler feedwater (*4*, *5*, *6*).

There is, first, the uncertainty, or tendency to tolerate statements of untruth, concerning the nature or manner of occurrence of silicon in natural water. In analyses, silicon is customarily determined and reported as silicon dioxide, SiO_2. That material is regarded, and properly so if it were other than a hypothetical fabrication of the analyst, as perhaps largely insoluble, a member of the chemically less inert category of suspended solids in water. The decision of Stabler in early work of the U. S. Geological Survey is cited as authority for the assignment of silicon to other than the group of ions in solution. As a matter of fact, his decision was dictated by convenience, to suit the immediate purpose. He recognized, and stated (*7*), that such practice, since long continued, was erroneous; that silicon undoubtedly enters into impurities classified as soluble. Recent experimenters and theorists on this perplexing subject have largely concurred in the belief that siliceous matter in the majority of natural waters is in solution (*5*, *8*, *9*, *10*). Truly it is a matter of practical observation that nonturbid waters of high siliceous content must of necessity contain their siliceous matter in apparent solution. Treatments for the silicon (or silica) content of water are diametrically opposed. Some presuppose to coagulate or flocculate silica from fine suspension; others are said to effect removal by means analogous to precipitation from solution. In actual fact, so-called chemical precipitation has been seen to take on the behavior of mechanical flocculation (*4*). Again, there is positive evidence that treatments of no supposed direct action, or at least of probable exclusive chemical reaction of an indirect nature, produce effective silica removal. The appearance of 15 to 30 per cent or more SiO_2 in sludges from the phosphate precipitation of calcium and magnesium from boiler water is a case in point. Just as the peacemaker has a place in every field of new knowledge, so is there need for an arbiter on the question of the constitution or state of siliceous matter in the majority of natural waters. Could not the contentions on both sides of the question of solution versus suspension be partially or largely valid? Much evidence (*4*) points to existence of an equilibrium or balance between siliceous matter in true solution and related siliceous matter dispersed in suspension, possibly as sub-colloidal SiO_2. The fact remains that, in the light of modern chemical theory, there is probably little difference whether we subscribe to the chemical combination view, assuming the mass law to control, or whether we attempt an explanation on the basis of colloid chemistry and invoke use of the adsorption isotherm.

Hardness, the conventional measure of the scale forming tendency of water, is not an index to the tendency of a siliceous water to encrust boilers. The opposite of common belief is, perhaps, true. As enunciated by the rule of Goldberg (*11*) the softer waters tend to be the more silicate bearing, from the nature

[1] Numbers in parentheses indicate references in appended literature cited.

of things. Furthermore, we have a premise variously attributed to Haupt, Braungard and sometimes to Goldberg (*11, 12*) that the tendency of a water to form siliceous boiler scale is measured by the ratio of its siliceous matter content to the sum of its conventional hardness and siliceous content. It is to be expected from the law of mass action that increase in the relative proportion of siliceous matter to sulphate and carbonate will promote precipitation of calcium and magnesium as silicates rather than in their compounds considered more usual to boiler scale. Lack of hardness appears, then, to indicate the siliceous scale-forming tendency of a water. Further proof that hardness forming materials are not the exclusive cause of boiler encrustations is seen in the finding of sodium in siliceous scales (*2*). Sodium salts have never been regarded as scale forming. They are first among the materials substituted for hardness in usual processes of water softening.

Even evaporation, as applied to the treatment of feedwater, is not a means for the complete elimination of siliceous matter from boilers. Carryover with evaporator vapor has been found sufficient to permit siliceous scales on furnace water-wall tubes, responsible for tube failure. Evaporator cleaning is, in such cases, a more than usual expense. Many chemical treatments attended with success are the reverse of ordinary practice. It has been contended (*13*) that the addition of magnesium salts to a siliceous water will render certain reagents efficacious in silicon removal. It is more usual in water treatment to strive to reduce the initial magnesium content. The question may well be asked whether the effectiveness of such treatment may not be due, in large part, to reduction of the ratio of siliceous matter to the sum of siliceous matter and hardness. Conventional softening of water, removing as it does little or no siliceous material, tends, in general, to promote siliceous scale formation. Siliceous scales have been encountered in most evident and serious form in soft water regions; they may take first place in many other localities with the advent of extensive water softening as for industrial and municipal water supply. Only when the last vestige of water hardness is removed with a chemical equilibrium established far to the side which opposes combination of siliceous matter with hardness-forming metallic ions can comparative freedom from siliceous scale be had in a soft water. Fortunately, siliceous scales composed only of silicon dioxide, SiO_2, although not impossible, are unusual. As the ratio of siliceous matter to siliceous matter plus hardness essentially becomes unity the silicate-scale forming tendency may be great, but there is a lack of necessary building material.

Another divergence from usual boiler-water control necessary with siliceous waters is found in the requirement of high effective alkalinity. Low boiler-water alkalinity has customarily been the objective to reduce the metal embrittlement danger and for conservation of the inhibiting agents used. Specification of pH values little more than 10, only high enough to aid corrosion prevention, has not been unusual. With high silicate contents of boiler water, pH values in the neighborhood of 11 become desirable (*14*). High sodium ion concentrations in the boiler water likewise take on new value in their tendency to convert siliceous matter into the soluble sodium silicates. Both high pH value and large sodium concentration probably add to the metal embrittlement hazard. When it is realized that many naturally-soft siliceous waters are singularly free from sulphate, the need for positive embrittlement protection with them becomes apparent.

A peculiarity of siliceous scale is its often reported sudden appearance after a long period of boiler operation with comparative freedom from trouble. That sudden growth of scale is more apparent than real. Thin films of siliceous matter are easily overlooked in the course of boiler inspection, especially when affected surfaces have been permitted to dry. When the heat insulating value of a usual carbonate-sulphate scale is equaled by that of a siliceous scale but a fraction of the thickness of the first named, it is to be expected that siliceous deposits might be disregarded until they have grown to dangerous thickness.

A marked difference is seen between the objectionable heat insulating value of siliceous scales and that of other scales. Stumper (*15*) summarizes comparative heat transfer coefficients, K, of various scales, as in the table. The constants are in the metric system of units and are consequently expressed as kilogram calories per meter per degree Centigrade per hour of time. It appears

Characterization of Scale	Heat Transfer Coefficient, K
Siliceous	0.2 to 0.5
Calcium Sulphate	0.5 to 7.0
Calcium Carbonate, Amorphous	0.2 to 1.0
Calcium Carbonate, Crystalline	0.5 to 5.0

that the ability of a siliceous scale to conduct heat is roughly from one-half to a tenth that of scales in which the chief constituents are calcium sulphate and calcium carbonate. Rise in the temperature gradient between water film and metal in a scale covered boiler plate must then be two to ten times as much with siliceous encrustation as with ordinary scale, when similar rates of heat transfer and thickness of deposit are considered. A siliceous film only a fraction of the thickness of a usual scale deposit might exceed the more usual scale in insulating value. The danger of markedly insulating thin deposits on heating surfaces is especially great with modern boilers wherein the metal temperature is normally near the safe maximum. It is elevation of the temperature gradient through boiler metal rather than reduction in overall thermal efficiency that is now to be feared from boiler scale (*6*).

An interesting situation not covered by ordinary experiences of boiler operation grows out of regulation or adjustment of blow down when siliceous deposits threaten. As has been explained, there is a tendency to discover siliceous scales only after their deposition is well under way. Even years' accumulation in a boiler, through many superficial cleanings, are, when found, ascribed to new, serious water conditions. A supposed preventive measure invoked in nearly all instances is that of increase in the blow down rate. The result of increased blow down scarcely ever fails to be a great increase in the rate of scale growth, thus apparently justifying the belief in suddenly changed problems. Reasons are obvious. Increase in blow down, as always, increases the amount of scale forming substance brought into the boiler in required raw water makeup. But more than that, excessive blow down reduces the pH alkalinity of the boiler water to values possibly less than pH 9 or 10, at which low values solubilities of the alkali

silicates are low. The vicious circle of blow down increase and siliceous deposition, once espoused by the boiler operator, speedily brings to a close the drama of long-time scale growth.

The steady hand and the informed mind, not swayed by paradoxical fact, are much the need of that boiler user who would deal effectively with silicon, both the old and the new element of boiler scale.

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Offers 50 Per Cent Discount on Increased Use of Electricity

In order to give customers the benefit of available surplus power at reduced rates, and incidentally to stimulate greater use of electricity among residential and commercial users, the Pacific Gas & Electric Company has announced a plan whereby all such customers will be entitled to a 50 per cent discount on the amount by which their bills exceed those for the corresponding months of the preceding year.

Dr. P. C. Ricketts well-known engineer and educator, and President of Rensselaer Polytechnic Institute died on December 10 at the age of 78. Doctor Ricketts had been a member of the faculty of that institution for 59 years and its president since 1901. Aside from his educational work he found time to engage in outside engineering activities and civic work and was regarded as an expert on patent litigation. He was an honorary member of the American Society of Mechanical Engineers, a member of the American Society of Civil Engineers, the Institute of Mining Engineers, and the Institute of Civil Engineers of Great Britain.

Power Peak Passes That of 1930

The production of electricity by the electric light and power industry of the United States for the week ending December 29, 1934, was 1,650,467,000 kwhr according to the Edison Electric Institute. This represented an increase of 7.2 per cent over the corresponding week of 1933, exceeded that of 1930 and was within approximately 4 per cent of the record peak of 1929.

With the exception of September, which was influenced by the textile strike all months of 1934 were well above those of 1933 and the average for the year showed an increase of nearly 8 per cent.

Projecting the curves to the end of the year the total output for 1934 will be found to have approximated the total for 1931, namely, about 85 billion kilowatthours.

From figures compiled for the twelve months ending October 31, 1934, the percentage of the energy generated by water power was 36.3 as compared with 40.8 for the previous year. The average consumption of electricity per customer had increased 3.6 and despite an average reduction in revenue per kilowatthour of 3.4 per cent the total revenue from ultimate consumers increased 2.5 per cent.

The installed generating capacity as of October 31, 1934 is given as:

Steam	23,800,100 kw
Water power	9,006,400
Internal Combustion	468,100
Total	33,274,600

This is a reduction of 229,700 kw during the year.

The total ultimate consumers is 24,767,255 which represents an increase of 560,000 over the previous year. By far the greater part of this increase was in domestic customers, the number of large industrial customers having remained practically the same.

Brown Instrument Company Consolidates with Minneapolis-Honeywell

The Brown Instrument Company of Philadelphia announces that it has consolidated with the Minneapolis-Honeywell Regulator Company of Minneapolis. It will, however, continue as a separate company with its existing organization but as a subsidiary of the latter company. Richard P. Brown will continue as President of The Brown Instrument Company and will become an officer and director of Minneapolis-Honeywell Regulator Company. The Brown Instrument Company sales and service facilities will be continued from the present main office and factory at Philadelphia and the district offices located throughout the country.

Howard Coonley, president of the Walworth Company, has been re-elected president of the American Standards Association for 1935. Mr. Coonley, who represents the American Society of Mechanical Engineers, has served two terms as president.

Economics of Preheated Air for Stokers*

Maintenance data were supplied by thirty-three operating companies covering 122 underfeed stokers operating with average air temperatures of 120 to 460 F and maximum air temperatures as high as 600 F. It was found that, aside from preheat temperatures, the factors affecting stoker maintenance are, area of stoker, coal burned per square foot per hour, and per cent of ash in the coal burned. The conclusions drawn from this study are that up to 300 F, the preheating of air supplied to underfeed stokers does not seem to increase maintenance above reasonable figures, but above 300 F or 350 F, there is a sharp increase in maintenance.

By R. E. DILLON

Supt. of Generation, Edison Electric Illuminating Company of Boston

and

By M. D. ENGLE

Asst. to Supt. of Station Engineering, Edison Electric Illuminating Company of Boston

THE development of the regenerative cycle for heating the boiler feedwater in steam-electric generating stations has resulted in returning the feedwater to the boiler room at much higher temperatures than was the practice twenty years ago. This higher feedwater temperature has materially reduced the heat reclaiming possibilities of economizers.

During this same period, the operation of boilers at greater and greater outputs, per foot of width, has materially increased the exit gas temperature from the boilers and has made it necessary to adopt some other heat reclaiming device to absorb the low-head heat in the flue gases leaving the economizer. Otherwise, the loss in boiler room efficiency would have, to a large extent, offset the higher turbine room efficiency obtained by the development of the regenerative cycle.

To further aggravate the condition, the adoption of higher steam pressures has increased the cost of boiler pressure parts to a point where it has become economically advisable to adopt the single-pass boiler and to operate it at still greater outputs per foot of width.

The combination of the regenerative cycle, higher pressure, greater output and single-pass design has raised boiler exit gas temperature far beyond the point where even an abnormally large economizer can absorb the heat necessary to give acceptable boiler room efficiencies. The development of the steaming economizer has helped somewhat but as a result of these conditions the air heater has become an almost necessary part of an economical, modern steam generating unit.

Unfortunately the air heaters, economizers and boilers have been proportioned to give the lowest overall cost of the steam generating unit without due consideration being given to the effect of highly preheated air on the maintenance cost and availability of the fuel-burning equipment. Stoker-fired units have been installed, incorporating air heaters which heat the air for combustion to as high as 600 F.

Operating engineers have found that high air temperatures result in higher stoker maintenance than is customary for stokers supplied with cold air, and furthermore, that which is even more important, high air temperatures reduce the availability of the stoker-fired steam-generating unit.

The designing engineer needs to know to what extent high air temperatures will increase maintenance and reduce availability if he is to design stations with low overall production costs. The operating engineer needs the same data in order that he may judge whether he is obtaining as good results as are to be expected from the equipment which he is operating.

Object of Study

The object of this study is to supply this information and to determine to just what extent stoker maintenance is a function of air temperature and other design and operating conditions.

It is realized that the factors affecting stoker maintenance are many and highly variable, but it is believed

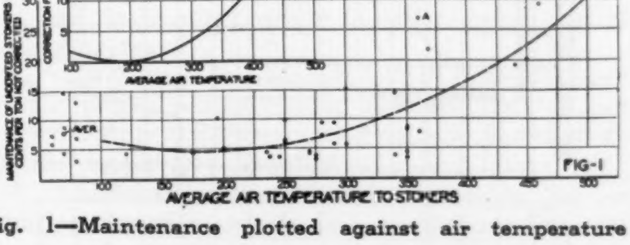


Fig. 1—Maintenance plotted against air temperature

that a study of the results obtained over long periods by stokers operating under widely varying conditions will be helpful.

The data used in this study was supplied by thirty-three operating companies and covers the operation of 122 stokers supplied with air at average temperatures varying from 120 F to 460 F and maximum air temperatures as high as 600 F. The operating period covered

* Presented at the Annual Meeting of the American Society of Mechanical Engineers, New York, Dec. 3–6, 1934.

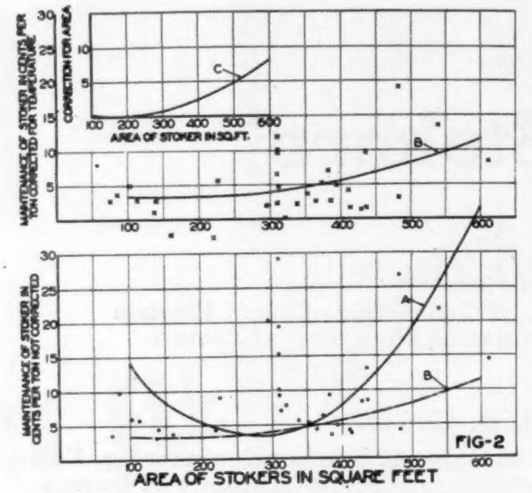


Fig. 2—Maintenance plotted against stoker area

by the maintenance figures represents approximately 475 stoker years.

Maintenance vs. Average Air Temperature

As a start, stoker maintenance was plotted against the average air temperature, as shown by Fig. 1, and by the method of moments the second degree curve that fits the points was found. The crosses in the lower left-hand corner of Fig. 1 show the stoker maintenance costs of eight stations operating cold-air stokers. These points fall very close to an extension of the curve drawn for the hot-air stokers.

It is not known that this curve represents the actual relation between maintenance and air temperature, but, no matter what reasonable curve may be drawn through these points, the trend will be very much the same.

The various points which were farthest from the curve, such as point A, were then examined. It was found that the three stokers represented by this point were burning an average of 50 lb of coal per hour per square foot of stoker area, and this was the highest rate for the 122 stokers covered by the data. Furthermore, these stokers each had an area of 482 square feet and were among the largest stokers covered by the data. Therefore, it was decided to plot the stoker maintenance against the other design and operating data, both uncorrected and corrected for temperature. The curve *C* on Fig. 1 shows the air temperature correction calculated for various air temperatures.

Fig. 2 shows the maintenance plotted against the area of the stokers and curve *A*, the second degree curve that fits the uncorrected points. Each point was corrected for temperature in accordance with curve *C*, Fig. 1, and curve *B*, Fig. 2 shows the second degree curve that fits these corrected points. Curve *C* shows the correction for area calculated from curve *B*. It is interesting to note how much better curve *B* fits the corrected points than curve *A* fitted the uncorrected points, and furthermore, how much more reasonable is curve *B*. It is quite obvious that area alone does not make the big difference in maintenance indicated by curve *A*.

In a similar manner, maintenance was plotted against average coal burned as shown by Fig. 3, both uncorrected and corrected for temperature, and a correction curve determined for the coal-burning rate as shown by curve *C*.

When maintenance was plotted against the per cent of ash in the coal burned, as shown by Fig. 4, a positive correction was obtained. The stations burning high-ash coals showed lower maintenance than those burning low-ash coals.

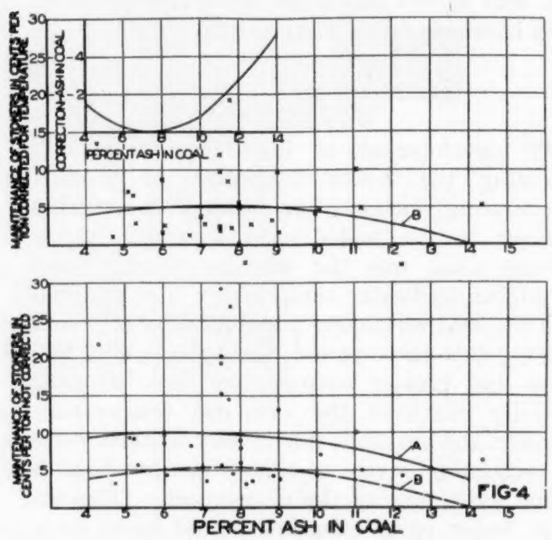


Fig. 4—Maintenance plotted against ash in coal

Curve *A*, Fig. 5, shows the uncorrected maintenance figures against the excess air measured at the sampling point used for setting the combustion control equipment of the particular boiler. It is to be noted that all high maintenance stokers reported operate with 35 per cent or less excess air. But, strange to relate, when the points were corrected for temperature and curve *B* determined for them, the correction was too small to be given serious consideration.

A plot of maintenance against stoker length, Fig. 6, did not give reasonable curves and so was not used in the final calculations.

Fig. 7 shows maintenance against the volatiles in the coal burned and seems to indicate that with low-volatile coals, higher maintenance is to be expected than with high-volatile coals.

Figs. 8 and 9 show maintenance against maximum

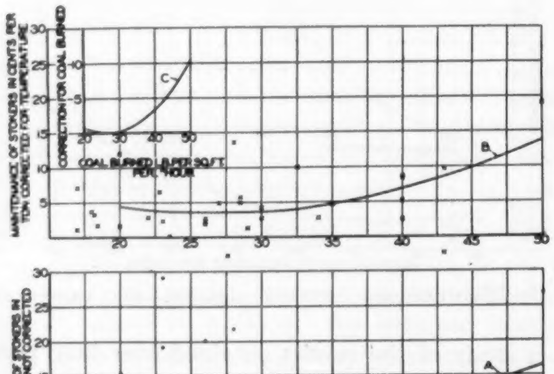


Fig. 3—Maintenance plotted against coal burned per square foot of grate area

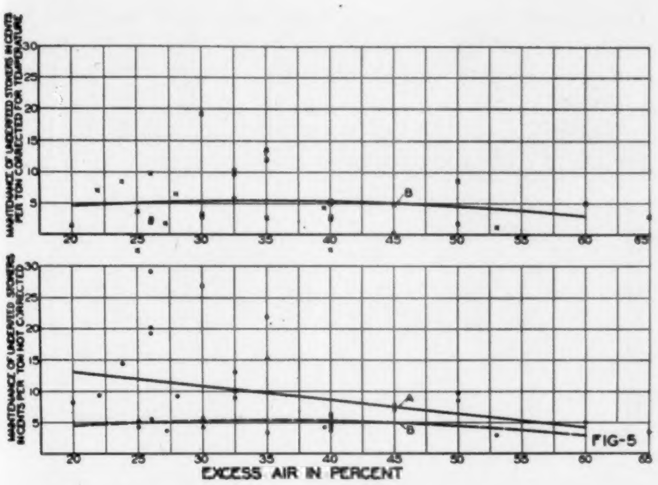


Fig. 5—Uncorrect maintenance vs. excess air

air temperature and maximum coal burned, but since, in most cases, neither of these variables would be expected to govern maintenance, these data have not been used in the final calculations.

Looking over the data given by these plots, it would appear that, outside of air temperature, the variables which most definitely affect stoker maintenance are: area of the stoker, Fig. 2; average coal burned, Fig. 3; and the per cent of ash in the coal burned, Fig. 4. Therefore, all points have been corrected for these three variables and curve *B*, Fig. 10, has been drawn for these corrected points. Curve *A*, Fig. 10, is a repetition of the original curve of uncorrected maintenance against average air temperature.

This new curve *B*, Fig. 10, now shows the relation between maintenance and average air temperature with some of the influence of the other three important variables removed, and should show a more nearly correct picture of the effect of air temperature alone on stoker maintenance.

This cut-and-try process could be continued, and each time the curve obtained would be closer to the actual facts. However, since the corrected curve *B*, Fig. 10, does not deviate a great deal from the original curve, further cut-and-try is not believed to be necessary and

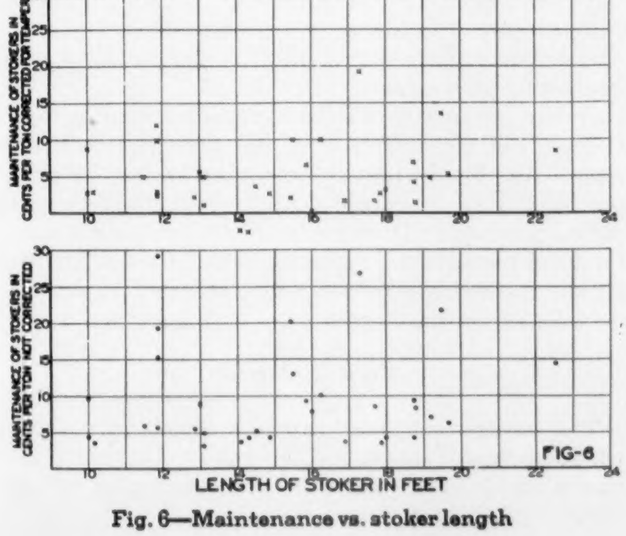


Fig. 6—Maintenance vs. stoker length

logical conclusions can be drawn from corrected curve *B*, Fig. 10.

Conclusions

A study of this curve indicates the following interesting facts:

Up to 300 F, the preheating of the air supplied to underfeed stokers does not seem to increase the maintenance above reasonable figures. Some operators are able to maintain maintenance costs in a reasonable range up to 350, but above 300 or 350 F, there is a very sharp increase in maintenance with increase in air temperature.

This means that for underfeed-stoker-fired installations, the boiler, economizer and air heater should be so proportioned as to keep the average temperature of the air supplied to the stoker down to about 300 F, unless abnormally high stoker maintenance can be countenanced for other advantages particular to the installation.

Changes and Operating Methods Used to Reduce Maintenance

For the benefit of those who have hot-air stokers installed, a study of the data obtained has been made to find the changes made and operating methods employed by the various companies to reduce stoker maintenance. Some of these may be applicable to your particular installation.

1. Many of the companies have found that the use of the so-called "thin tuyère" reduces maintenance. These tuyères are a little over one-half as thick as the standard tuyère and have air openings and cooling ribs so located as to maintain a lower tuyère temperature than is possible with the standard tuyère.
2. Many companies have reduced the number of pushers installed with the original stoker. The pushers removed are replaced with a dead plate designed for the particular type of stoker.
3. With hot-air stokers every attempt possible should be made to seal off the retorts and cause all air to be delivered through the tuyères. Hot air coming through the retorts causes serious burn-outs.
4. Carrying the ashes higher in the clinker pit reduces extension grate, clinker grinder and wall maintenance and maintains a more uniform fuel bed and lower combustible loss in the ashes.
5. The use of higher excess air, by carrying a thinner fuel bed, quite often results in lower overall cost of generating steam.
6. The finding of the correct fuel-bed shape, obtained by the proper pusher motion, for each type of coal burned, results in lower operating costs, higher capacity and fewer operating difficulties.
7. Careful adjustment of pusher motion across the width of the stoker results in more uniform fires and consequent advantages.
8. For the lower air temperature installations, spray lubrication of the operating mechanisms under the stoker may show surprisingly beneficial results.
9. Water sprays turned on periodically under the stoker, or water admitted through the nose of certain tuyères at times, are used to crack off the slag which accumulates on the tuyères of hot-air stokers.
10. The keeping of a cumulative graphic record of

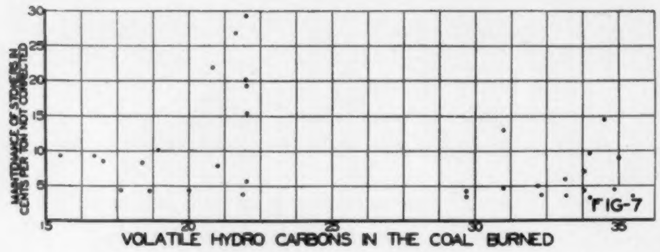


Fig. 7—Maintenance vs. volatiles in the coal

maintenance and steam output or coal burned for each stoker over a long period of time is a big help in pinning down the particular stokers which are showing high maintenance. Two stokers which are apparently duplicates may show wide variation in maintenance costs.

11. Low alloy cast-iron stoker parts have been tried

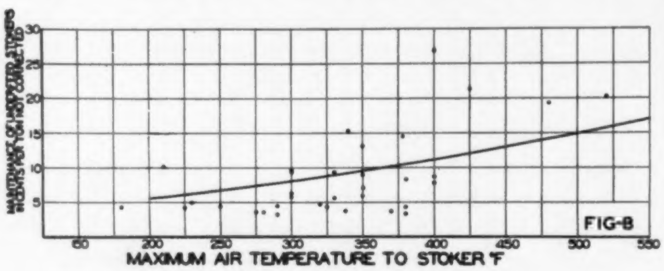


Fig. 8—Maintenance plotted against maximum air temperature

by a number of companies, but so far no one has been able to show that the higher cost of the alloy parts is economically justified. Good, sound castings, however, seem to help maintain low maintenance costs.

Chain Grate Stokers

Maintenance data were also obtained from seven companies operating 77 chain grate stokers supplied

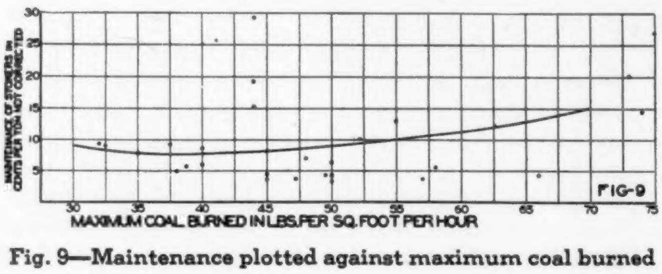


Fig. 9—Maintenance plotted against maximum coal burned

with hot air varying in average temperature from 100 to 375 F. The data represented 440 stoker years of operation. A plot of maintenance against air temperature did not give anything from which logical conclusion could be drawn. The same might also have been true for underfeed stokers had it not been possible to obtain data on stokers operating with average temperatures above 375 F.

Table I gives the limits for the data obtained for both the chain grate and underfeed stokers.

TABLE I

	Chain Grate Stokers	Underfeed Stokers
Number of companies	7	33
Number of stokers	77	122
Stoker years represented	441	475
Range of width in feet	7'9" to 24'0"	7'6" to 30'0"
Range of length in feet	15'0" to 22'9"	10'0" to 22'6 3/4"
Range of area in square feet	155 to 528	75 to 611
Range of average air temperature, F	100 to 375	120 to 460
Range of maximum air temperature, F	100 to 500	100 to 600
Range of excess air	20% to 50%	20% to 70%
Range of maximum coal burned (lb per sq ft per hr)	36.8 to 72	21 to 75
Range of average coal burned	25.8 to 47 pounds	17 to 50 pounds
Range of moisture in coal	10% to 21%	0.4% to 14.52%
Range of volatile in coal	1.76% to 33.46%	15.5% to 40.7%
Range of ash in coal	6.00% to 14.70%	4.3% to 14.33%
Range of fusion temperature of ash, F	2000 to 2400	2050 to 2900
Range in maintenance in cents per ton of coal burned	0.4¢ to 6.8¢	3.17¢ to 29.2¢

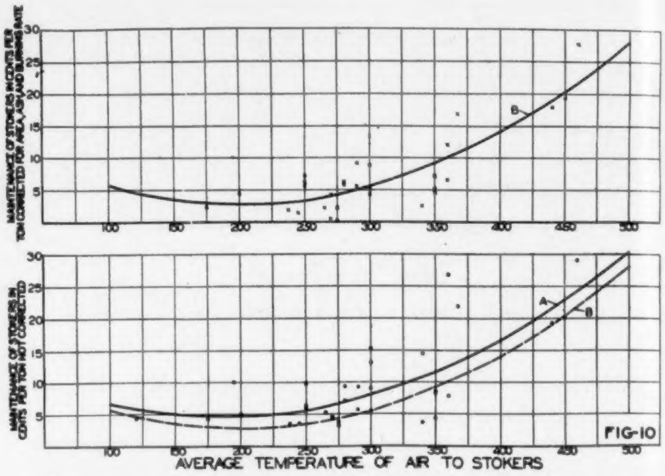


Fig. 10—Relation between maintenance and average air temperature, corrected and uncorrected for variables

A study of this table shows the interesting facts that chain grate stokers supplied with hot air and burning the types of fuel for which they are suited can match the underfeed stoker in coal burning capacity in pounds per square feet per hour and apparently operate with lower maintenance cost.

Practical Aspect as an Aid to the Designing Engineer

Knowing the local conditions, a designing engineer could use the curves to determine the economics of increasing the size of the air heater to obtain higher boiler room efficiency.

From curve *B*, Fig. 10, it can be seen that increasing the air temperature from 350 to 400 F will result in about 5 cents per ton increase in stoker maintenance. Since 50 deg F rise in air temperature represents about 1 per cent in boiler room efficiency, for $5.00 per ton coal, the increase in stoker maintenance would absorb all of the saving in coal and no savings would be available to pay the fixed charges on the cost of the larger air heater. Furthermore, the higher stoker maintenance indicates a lower boiler availability, and the larger air heater would be a losing proposition.

If it is desired to compare the maintenance cost of existing hot air stokers with the average, the maintenance costs for the particular installation can be plotted on the curves. The corrections used are all given by the curves presented. It may be possible to apply corrections for local conditions pertaining to any particular installation, method of bookkeeping, etc., and explain any deviation from the curves.

Acknowledgments

This paper would not have been possible without the whole-hearted cooperation of many operating companies and their engineers. The authors wish to thank them for their cooperation.

Survey of Engineers to Show Trend of Technical Activity

By FREDERICK M. FEIKER

Executive Secretary
American Engineering Council

A survey by the U. S. Bureau of Labor Statistics in cooperation with the American Engineering Council, covering approximately one-third the engineers in the country, is now under way for the purpose of ascertaining data on employment, salaries (past and present), work in professional and non-professional lines and to what extent different industries are holding their technical men.

FUTURE technical improvements in trade and industry will depend to no small degree upon the continued advancement of the engineering profession. If steps toward the raising of efficiency, the prevention of waste and the lowering of unit costs are to keep pace with the needs of this country, two conditions must be met:

1. Enough engineers must be employed now to plan ahead for limited improvements through the depression and for extensive development work during recovery.
2. Enough engineers must be kept within the profession so that there will be no shortage of experienced men when business becomes normal.

Most of the past studies in the field of technology have dealt not with men but with methods, materials and machinery. The forthcoming survey of the engineering profession by the U. S. Department of Labor directs attention for the first time to the technologists themselves—to the men who make technical improvements possible.

It is already known that even in boom times, the ratio of engineers to total employees in most industries was far too low for the adequate use of technical knowledge in stepping up efficiency. In agriculture and forestry, for example, only 0.01 per cent of the employed were listed as engineers under the Census of 1930, according to a study by American Engineering Council. In wholesale and retail trade, only 0.02 per cent were engineers; textile and clothing industries, 0.06 per cent. The figures range up to 3.51 per cent for public utilities.

As to 1934, the Labor Department survey is about to tell the story. Whether the drop in engineering employment has been in proportion to the general growth of unemployment, and whether some industries are holding their technical staffs, are matters of significance to those engaged in the production of new equipment or in the modernization of existing plants. This information is expected to serve as an indication of technological activity now under way, pointing toward the fields in which improvements are most needed—a rich undeveloped market.

The U. S. Bureau of Labor Statistics is making the survey in cooperation with the American Engineering Council and technical societies throughout the country. Dr. Isador Lubin, Commissioner of Labor Statistics, explains it as follows:

"The survey will cover roughly one-third of the 225,000 persons listed as engineers under the Census of 1930 and is intended to be a representative sample. Confidential questionnaires will supply data as to the location, age and education of individuals and their employment and earnings at stated intervals since 1928. The types of employers (whether private firms, Federal agencies, etc.) and the present duties, title and salary of each engineer will be listed. Individuals will be asked how they seek employment—whether through private or public agencies, engineering societies, personal contact or other means. Questions also will be included as to the licensing of engineers; their rights as to patents and improvements; whether their work is temporary or permanent and whether under contract.

"These and other questions will show how many of the engineers are unemployed and from what fields they have been displaced; how many have been forced into sub-professional and non-professional work; what has happened to salaries; and what lines, if any, are offering new employment.

"This will be the most comprehensive survey of a professional group ever undertaken on a national scale. As well as helping the graduate engineers to adjust to current conditions, the findings are expected to affect the policies of engineering colleges so that new graduates will be trained toward work likely to be in demand rather than along lines where there is no immediate prospect.

"As well as reflecting the immediate situation, the returns will show trends, tying into the Census of 1930 and past surveys of the engineering societies. In future, the survey will stand as a fixed point to which similar counts of the profession may be related. In dealing with professional people, it is believed that we can secure an unusually high return as to accuracy and completeness."

Engineers and other professional groups, Dr. Lubin points out, have not been faced with a serious unemployment crisis prior to this depression. Consequently, not much attention has been directed to employment problems within these groups and the need for statistical guidance has become acute. When the final figures are at hand, it will be possible to apply the principle of engineering analysis to the engineers themselves without any guesswork as to the actual trends and conditions.

REPRESENTATIVE C·E CONTRACTS—1934

★FORD MOTOR COMPANY,
Detroit, Mich.: One C-E bent tube boiler of special design; rated maximum output, 900,000 lb. of steam per hour; design pressure, 1,400 lb.; total steam temperature, 900 F. Equipped with C-E water walls and screens with suspended walls, two C-E fin type economizers, and two C-E plate type air heaters. Fired by C-E pulverized fuel system.

★CHEVROLET MOTOR CAR COMPANY,
Detroit, Mich. (Baltimore, Md. Plant): Three C-E 4-drum bent tube boilers; rated maximum output, 45,000 lb. of steam per hour each; design pressure, 225 lb. Equipped with C-E water walls. Fired by C-E multiple retort stokers.

★COLGATE-PALMOLIVE-PEET COMPANY,
Jersey City, N. J.: Two C-E 4-drum bent tube boilers; rated maximum output, 85,000 lb. of steam per hour each; design pressure, 440 lb.; total temperature, 600 F. Equipped with C-E side water boxes. Fired by C-E Coxe traveling grate stokers.

★COLGATE-PALMOLIVE-PEET COMPANY,
(Jeffersonville, Ind., Plant): One C-E 4-drum bent tube boiler; rated maximum output, 35,000 lb. of steam per hour; design pressure, 425 lb. Equipped with C-E water walls and water cooled arch, and C-E economizer. Fired by C-E Green forced draft chain grate stoker.

★CONTAINER CORPORATION OF AMERICA,
Chicago, Ill.: One C-E 4-drum bent tube boiler; rated maximum output, 70,000 lb. of steam per hour; design pressure, 448 lb.; total steam temperature, 680 F. Equipped with C-E side water walls and rear arch water screen. Fired by C-E Green forced draft chain grate stoker.

★DETROIT EDISON COMPANY,
(Connors Creek Plant): Two twin set bent tube boilers of special design; rated maximum output, 392,000 lb. of steam per hour; design pressure, 710 lb.; total steam temperature, 850 F. Equipped with C-E water walls, C-E economizers and C-E plate type air heaters. A previous order for two similar units, also received by C-E, was completed this year.

★DUPONT RAYON COMPANY,
Ampthill, Va. (Spruance Plant): One C-E 4-drum bent tube boiler; rated maximum output, 120,000 lb. of steam per hour; design pressure, 450 lb.; total steam temperature, 700 F. Equipped with C-E completely water cooled furnace, C-E tubular air heater and Elesco superheater. Fired by C-E pulverized fuel system.

★FIRESTONE TIRE & RUBBER COMPANY,
Akron, O.: One C-E sectional header boiler; rated maximum output, 350,000 lb. of steam per hour; design pressure, 1,400 lb.; total steam temperature, 769 F. Equipped with C-E completely water cooled furnace, C-E plate type air heater and Elesco superheater. Fired by C-E pulverized fuel system. In addition to the above contract the Firestone Tire & Rubber Company also ordered a C-E Green forced draft chain grate stoker for another boiler of 875 hp. rating.

★CAPITAL ELECTRICITY WORKS,
Nanking, China: Two C-E steam generators; rated maximum output, 133,200 lb. of steam per hour each; design pressure, 525 lb.; total steam temperature, 725 F. Equipped with C-E plate type air heaters, C-E water walls and screens. Elesco superheaters.

★Rated over $1,000,000.

★HUMMEL-ROSS FIBRE CORPORATION,
Hopewell, W. Va.: Two C-E Murray-Waern System chemical and waste heat recovery units. These units are designed for service in connection with the production of paper pulp. Each unit includes smelter boiler with water cooled walls, waste heat boiler, superheater and air heater—all of special C-E design and construction. Calculated steam production, each unit, when operated at capacity is 500,000 lb. of steam, from and at 212 F., per 24 hours.

★PENNSYLVANIA SALT MANUFACTURING CO.,
Wyandotte, Mich.: One C-E 4-drum bent tube boiler; rated maximum output, 150,000 lb. of steam; design pressure, 448 lb.; total steam temperature, 700 F. Equipped with C-E water walls, screen and water cooled arch, C-E plate type air heater and Elesco superheater. Fired by C-E pulverized fuel system.

U. S. WAR DEPARTMENT,
Wright Field, Dayton, O.: Two C-E 4-drum bent tube boilers; rated maximum output, 62,500 lb. of steam per hour, each; design pressure, 200 lb. Equipped with C-E water walls. Fired by C-E pulverized fuel system.

★U. S. INDUSTRIAL ALCOHOL COMPANY,
New York, N. Y. (Curtis Bay, Md. Plant): Two C-E 4-drum bent tube multiple circulation boilers; rated maximum output, 125,000 lb. of steam per hour; design pressure, 650 lb.; total steam temperature, 685 F. Equipped with C-E water walls and C-E plate type air heaters. Fired by C-E pulverized fuel system.

★WESTINGHOUSE AIR BRAKE COMPANY,
Wilmerding, Pa.: Two C-E 4-drum bent tube boilers; rated maximum output, 68,000 lb. of steam per hour each; design pressure, 575 lb. Equipped with C-E water walls and Elesco superheater.

CITY OF HASTINGS,
Hastings, Neb: One C-E 4-drum bent tube boiler; rated maximum output, 55,000 lb. of steam per hour; design pressure, 440 lb. Equipped with C-E fin tube econmizer, C-E tubular counterflow air heater, and Elesco superheater. Fired by C-E pulverized fuel system.

★DENVER TRAMWAY CORPORATION,
Denver, Colo.: Five C-E 4-drum bent tube boilers; rated maximum output, 50,000 lb. of steam per hour each; design pressure, 233 lb.; total steam temperature, 497 F.

DUVAL TEXAS SULPHUR COMPANY,
Boling, Texas: Four C-E low head bent tube boilers; rated maximum output, 37,500 lb. of steam each; design pressure, 115 lb.

STATE HOSPITAL FOR NERVOUS DISEASES,
Benton, Ark.: Three C-E 275 hp. low head bent tube boilers.

UNIVERSITY OF MISSISSIPPI,
Oxford, Miss.: Two C-E 315 hp. low head bent tube boilers.

NEW HAMPSHIRE STATE HOSPITAL,
Concord, N. H.: Two C-E 316 hp. box header boilers.

OKLAHOMA AGRICULTURAL & MECHANICAL COLLEGE
Stillwater, Okla.: Two C-E 294 hp. low head bent tube boilers.

★THERMOID RUBBER COMPANY,
Trenton, N. J.: Two C-E 295 hp. 4-drum bent tube boilers and two C-E Coxe traveling grate stokers for firing same.

CREIGHTON MEMORIAL ST. JOSEPH'S HOSPITAL,
Omaha, Neb.: Two C-E 294 hp. low head bent tube boilers and two C-E Green forced draft chain grate stokers for firing same.

WESTERN STATE COLLEGE,
Gunnison, Colo.: C-E 181 hp. low head bent tube boiler and C-E Type E stoker for firing same.

CAMPERDOWN COMPANY, INC.,
Greenfield, S. C.: C-E 400 hp. low head bent tube boiler and C-E Type E stoker for firing same.

SWIFT MANUFACTURING COMPANY,
Columbus, O.: C-E 486 hp. box header boiler and C-E Type E stoker for firing same.

★UNION WAREHOUSE CORPORATION,
Union City, N. J.: C-E 400 hp. low head bent tube boiler and C-E Type E stoker for firing same.

U. S. ARMY DREDGE,
"Blackwater": Two C-E 193 hp. marine boilers.

★PUBLIC SERVICE OF COLORADO,
Denver, Colo. (La Grange Station)
C-E 4-drum bent tube boiler; rated maximum output, 75,000 lb. of steam per hour; design pressure, 448 lb.

DAH YIH CHENG COTTON MILL,
Shanghai, China: C-E 267 hp. 4-drum bent tube boiler.

★RATH PACKING COMPANY,
Waterloo, Iowa: C-E 4-drum bent tube boiler; rated maximum output, 40,000 lb. of steam per hour; design pressure, 450 lb.

★ARMSTRONG PAINT & VARNISH COMPANY,
Chicago, Ill.: C-E 253 hp. low head bent tube boiler.

SHELBY COUNTY PENAL FARM,
Mullens Station, Tenn.: C-E 327 hp. low head bent tube boiler.

CITY OF MIAMI,
Miami, Fla.: C-E 358 hp. waste heat boiler.

★CHAMPION FIBRE COMPANY,
Canton, N. C.: Four C-E traveling grate stokers for firing black liquor chemical recovery units, and C-E smelter top boiler for same.

★SWIFT & COMPANY,
Chicago, Ill. (Harrison, N. J., Plant): Four C-E Type E stokers for 520 hp. boilers.

★MICHIGAN SUGAR COMPANY,
Saginaw, Mich.: C-E Type E stoker for pulp dryer. A repeat order for two additional C-E Type E stokers was also received this year by C-E from this company for a similar application in their Sebewaing, Mich., plant.

★NATIONAL ANILINE & CHEMICAL COMPANY,
Inc., New York, N. Y., (Buffalo, N. Y., Plant): Two C-E Coxe traveling grate stokers for 509 hp. boilers.

★AMERICAN CAN COMPANY,
Chicago, Ill. (Constantine, Mich., Plant): Two C-E Green forced draft chain grate stokers for 400 hp. boilers.

COMBUSTION

ENGINEERING

Kentucky Coals—
Their Classification and Analyses

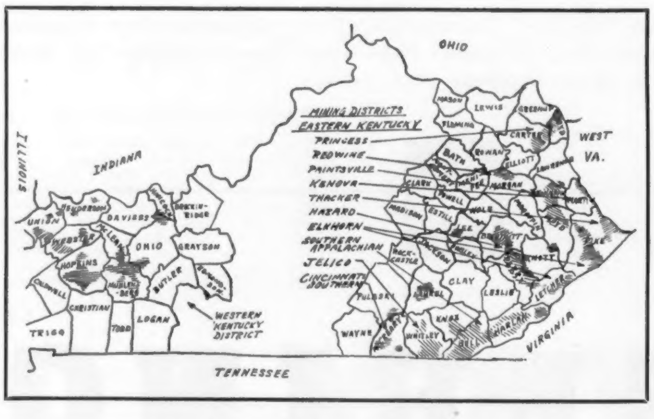
By P. B. PLACE,

Combustion Engineering Company, Inc.

This is the third of a series of articles in which the author discusses location, analyses and characteristics of various coals of the United States. The first, or general discussion, appeared in the October issue and in the November issue Ohio coals were taken up in detail. The present article identifies the various seams and trade names of Kentucky coals, discusses their characteristics and indicates their adaptability to stoker and pulverized coal firing.

KENTUCKY has two distinct coal bearing regions as shown by the shaded areas on the map. The Eastern area is adjacent to West Virginia, Virginia and Ohio and the coals produced in this region resemble those from these neighboring states. The Western area is adjacent to Southern Illinois and Indiana and its coals are similar in many respects, to those mined in these states.

As in other states, these coal areas are divided into smaller fields and districts of local mining activity. The Eastern area is divided into four producing fields and subdivided into ten or more mining districts. The Western area is usually considered as a unit. Table I gives the principal fields and districts in Kentucky and the map shows their approximate size and location.



Coal bearing regions of Kentucky

Table II gives the relative bituminous coal production in the principal producing states in the United States during recent years, showing Kentucky as the fourth largest producer. Kentucky and Illinois contribute about equally to twenty two per cent of the total production of the United States.

TABLE I

PRINCIPAL COAL FIELDS AND DISTRICTS OF KENTUCKY

I. Eastern Kentucky
- A. Northeastern, Big Sandy, or Elkhorn Field
  - 1. Princess District
    - a. Boyd County
    - b. Carter County
  - 2. Redwine District
    - a. Morgan County
  - 3. Paintsville District
    - a. Johnson County
    - b. Floyd County
  - 4. Elkhorn District
    - a. Western Pike County
    - b. Letcher County
- B. Southeastern Field
  - 1. Southern Appalachian District
    - a. Harlan County
    - b. Bell County
    - c. Knox County
  - 2. Jellico District
    - a. Whitely County
  - 3. Cincinnati Southern District
    - a. McCreary County
- C. Hazard Field
  - 1. Hazard District
    - a. Lee County
    - b. Breathitt County
    - c. Perry County
- D. Williamson Field
  - 1. Kenova District
    - a. Martin County
  - 2. Thacker District
    - a. Eastern Pike County

II. Western Kentucky
- A. Western Kentucky Field
  - a. Muhlenberg County
  - b. Hopkins County
  - c. Webster County
  - d. Union County
  - e. Ohio County
  - f. Henderson County
  - g. Daviess County
  - h. McLean County

Table III gives the relative production of the principal coal counties in Kentucky. The Eastern region produces 75 to 80 per cent of the state production. Harlan, Perry, Pike and Letcher counties are the principal producers in the Eastern fields and Muhlenberg, Hopkins and Webster counties produce most of the coal from the Western field.

Different investigators have introduced a variety of names and classifications for Kentucky coal seams that make identification of these coals confusing. For example, the coal bearing rocks in the Eastern area have been divided into at least three different classifications of formations variously named as follows:

1

Bryson formation
Hignite "
Catron "
Mingo "
Hance "
Lee "

2

Harlan sandstone formation
Wise "
Gladeville sandstone "
Norton "
Lee "

3

Dunkard formation
Monongahela "
Conemaugh "
Alleghany "
Pottsville "

The first classification is local to the state and indicates no link with seams and beds in adjacent states. The second is that applied to similar rock formations in Virginia. The third is the standard classification of Pennsylvania, Ohio and Maryland and is the most desirable since it indicates the continuity of coal seams and rock formations through a large portion of the Appalachian Field.

Some Seams Are Known by Different Names in Different Counties

Further confusion results from the fact that the various coal seams found at different levels in these rocks have been variously named. Even the same seam may have different names in different counties and in only a few cases does the same seam have the same name in adjacent states. Thus for example, the Dean seam in Harlan County is called the Fireclay seam in Letcher County, No. 7 seam in Lee County of Virginia, and Phillips seam in Wise County of Virginia. Similarly, No. 9 and No. 11 seams in Western Kentucky are called No. 5 and No. 6, respectively, in Illinois and Indiana. Elkhorn, Taggart, Keokee, Roda and Kentucky No. 3 have all been used more or less interchangeably for naming the Lower Mercer seam and No. 2 Gas, Imboden, Pond Creek, Warfield and Lower Elkhorn are names similarly associated.

The following list gives the names of the principal coal beds in Eastern Kentucky. These seams occur chiefly in the Pottsville, Alleghany and Lower Conemaugh Formations and are named in the order in which they occur from upper to lower bed.

TABLE II

RELATIVE PRODUCTION OF BITUMINOUS COAL IN PRINCIPAL PRODUCING STATES 1929 - 1932

State	1929	1930	1931	1932
West Virginia	25.9	26.0	26.5	27.7
Pennsylvania	26.8	26.6	25.6	24.1
Illinois	11.4	11.5	11.6	10.8
Kentucky	11.3	11.0	10.5	11.4
Ohio	4.4	4.8	5.4	4.5
Indiana	3.4	3.5	3.7	4.3
Alabama	3.4	3.3	3.1	2.5
Virginia	2.4	2.3	2.5	2.5
	89.0	89.0	88.9	87.8

TABLE III

RELATIVE PRODUCTION OF BITUMINOUS COAL IN PRINCIPAL PRODUCING COUNTIES OF KENTUCKY 1929 - 1932

County	1929	1930	1931	1932
Harlan	23.3	24.9	23.4	19.5
Perry	9.6	10.2	12.5	12.5
Pike	12.2	11.6	11.7	11.3
Letcher	10.8	11.7	11.4	10.0
Muhlenberg	8.1	5.8	7.0	9.3
Floyd	8.1	8.7	8.3	8.1
Hopkins	7.2	7.6	7.0	8.0
Webster	4.3	3.3	3.5	4.6
Bell	4.8	4.3	3.5	3.3
Johnson	2.0	1.9	1.7	2.7
	90.4	90.0	90.0	89.3

TABLE IV

INDIVIDUAL ANALYSES OF COALS
HARLAN BED-HARLAN COUNTY

As Received		Moisture and Ash Free							
Moist.	Ash	Volatile Matter	Fixed Carbon	Sulphur	Hydrogen	Carbon	Nitrogen	Oxyen	Btu / lb
2.6	3.5	39.1	60.9	0.8	5.6	84.1	1.7	7.8	15040
3.0	3.9	39.4	60.6	1.0	5.6	83.9	1.8	7.7	14970
3.2	3.3	39.8	60.2	1.0	5.5	84.4	1.8	7.3	15130
3.4	4.0	38.0	62.0	0.9	5.6	84.2	1.8	7.5	15010
3.1	2.8	39.4	60.6	0.8	5.6	84.0	1.8	7.8	15060
3.7	2.4	39.3	60.7	0.8	5.7	83.9	1.7	7.9	14990
Average									
M	2 - 4								
A	2 - 4	39.2	60.8	0.9	5.6	84.1	1.8	7.6	15035

INDIVIDUAL ANALYSES OF COALS
NO. 9 BED-MUHLENBERG COUNTY

Moist.	Ash	Volatile Matter	Fixed Carbon	Sulphur	Hydrogen	Carbon	Nitrogen	Oxyen	Btu / lb
8.8	8.8	45.3	54.7	4.3	5.5	80.2	1.7	8.3	14410
8.7	7.6	45.1	54.9	3.2	5.4	80.8	1.7	8.9	14580
8.8	8.6	43.8	56.2	4.3	5.3	79.1	1.8	9.5	14410
8.2	10.1	44.5	55.5	4.1	5.5	79.8	1.9	8.7	14410
8.5	9.2	44.2	55.8	4.2	5.4	80.2	1.7	8.5	14450
Average									
M	8 - 9								
A	7 -10	44.6	55.4	4.0	5.4	80.0	1.8	8.8	14450

TABLE V

AVERAGE ANALYSES OF KENTUCKY COALS

1. Eastern Kentucky

County	Moisture and Ash Free								As Received	
	V.M.	F.C.	S	H	C	N	O	Btu	M	A
Harlan	39.7	60.3	0.9	5.6	83.9	1.8	7.8	15010	2-5	2-6
Perry	40.2	59.8	0.8	5.5	83.8	1.9	8.0	14940	3-5	3-8
Pike	36.3	63.7	0.8	5.3	85.3	1.4	7.2	15250	2-4	4-7
Letcher	39.2	60.8	0.7	5.5	85.1	1.7	7.0	15120	3-4	2-4
Bell	40.5	59.5	1.3	5.7	83.6	2.0	7.3	15000	2-6	2-8
Knox	40.5	59.5	1.1	5.6	83.2	1.9	8.1	14870	4-6	5-7
McCreary	40.8	59.2	1.7	5.6	82.8	1.5	8.4	14850	3-5	4-9

2. Western Kentucky

County	V.M.	F.C.	S	H	C	N	O	Btu	M	A
Muhlenberg	44.7	55.3	4.0	5.4	80.0	1.8	8.8	14450	8-9	7-10
Hopkins	44.6	55.4	3.9	5.5	80.5	1.7	8.4	14440	8-9	5-10
Webster	42.6	57.4	3.3	5.4	81.1	1.7	8.5	14645	4-10	7-10
Ohio	44.8	55.2	4.0	5.4	79.5	1.7	9.4	14375	8-10	8-11
Union	44.2	55.8	4.3	5.5	81.1	1.7	7.4	14670	3-10	9-12
Henderson	45.5	54.5	3.8	5.3	78.9	1.8	10.2	14175	9-13	8-12

TABLE VI

PROXIMATE ANALYSES OF TYPICAL KENTUCKY COALS

Seam	As Received						M & A Free	
	M	A	V.M.	F.C.	S	Btu/lb	V.M.	Btu/lb
Millers Creek,Van Lear	6.4	2.6	35.6	55.4	0.8	13555	39.2	14900
Elkhorn,Sandy Lick,No 3	3.4	4.0	36.8	55.8	0.8	14000	39.7	15120
Pond Creek,Warfield	1.4	5.7	35.4	57.5	0.8	13700	38.1	14750
No 2 Gas	3.2	5.1	33.0	58.7	0.6	13880	36.0	15150
Hazard No 4,Fireclay	3.8	4.2	36.7	55.3	0.7	13755	39.9	14950
Hazard No 6	4.5	6.5	37.2	51.8	0.7	13300	41.7	14940
Flag, No 7, Cornett	4.3	6.1	36.4	53.2	0.7	13350	40.6	14890
Amburgy, Low Splint	1.9	7.5	37.8	52.8	1.3	13600	41.7	15020
Harlan	3.3	3.9	36.9	55.9	0.9	13960	39.8	15050
Wallins	3.7	3.9	38.6	53.8	0.6	13800	41.8	14950
Kellioka,Keokee,"C"	2.6	4.7	35.5	57.2	0.7	13900	38.2	14980
High Splint,Hindman	3.4	3.4	35.6	57.6	0.7	14100	38.2	15120
Leonard	3.3	3.4	35.4	57.9	0.6	14150	38.0	15170
Jellico,Straight Creek	4.8	5.5	36.0	53.7	1.1	13450	40.1	14980
Blue Gem	4.0	6.9	35.3	53.8	0.7	13340	39.6	14970
Dean	4.8	6.5	35.6	53.1	1.0	13300	40.2	15010
Mason	3.2	4.2	37.8	54.8	1.4	14000	40.8	15130
Poplar Lick	3.2	6.8	37.7	52.3	1.9	13410	41.9	14920
Sandstone Parting	3.1	6.9	35.1	54.9	1.0	13460	39.0	14960
Creech	2.6	4.4	37.2	55.8	1.1	14000	40.0	15060
Hignite	3.7	4.2	36.4	55.7	0.7	13730	39.5	14920
Lower Hignite	5.7	4.3	36.8	53.2	1.0	13400	40.9	14900
Average for Eastern Kentucky	3.6	5.0	36.3	55.1	0.9	13710	39.8	14995
No 9	4.8	9.0	36.7	49.5	3.3	12490	42.5	14500
No 11	7.2	10.5	36.9	45.4	4.0	12150	44.8	14750
No 12, Caney Fork	4.6	10.9	36.8	47.7	1.6	12500	43.6	14800
No 14, Nebo	8.7	9.0	35.3	47.0	2.9	11900	42.9	14460
Baker	5.2	8.7	35.1	51.0	1.3	12695	40.7	14750
Empire	10.8	3.8	35.7	49.7	1.8	12420	40.8	14200
Mannington	9.4	8.1	34.0	48.5	3.0	12080	41.2	14640
Average for Western Kentucky	7.3	8.6	35.7	48.4	2.6	12320	42.3	14585

Note: The above typical analyses are from a Keystone Coal Catalogue.

Hilton (Leslie County); Stamper (Letcher County)
Upper Freeport; Kentucky No. 9; Hindman; High Splint
Lower Freeport; Kentucky No. 8; Francis
Middle Kittanning; Kentucky No. 7; Flag; Cornett; Wallins; Banner Fork
Lower Kittanning; Kentucky No. 6; Hazard No. 6 (Perry County)
Brookville; Kentucky No. 5; Haddix (Letcher County); Limestone (Harlan County)
Upper Mercer; Kentucky No. 4; Fireclay; Dean; Hazard No. 4; Hyden
Whitesburg
Amburgy (Letcher County); Low Splint (Harlan County)
Lower Mercer; Kentucky No. 3; Elkhorn; Sandy Lick; Taggart; Keokee, Darby
Harlan; Straight Creek; Jellico: "A" Seam
Imboden; Lower Elkhorn; No. 2 Gas; Pond Creek (Pike County), Warfield
Upper Blue Gem
Bacon Creek; Lower Blue Gem
Quakertown; Kentucky No. 2; Van Lear; Miller's Creek; Lewis
Sharon; Kentucky No. 1; Dwale

The coal bearing formations in the Western area have been named as follows:

Dixon	formation
Lisman	"
Mulford	"
De Koven	"
Trade Water	"
Caseyville	"

TABLE VII

AVERAGE ANALYSIS OF AN EASTERN KENTUCKY BITUMINOUS COAL

	As Received	Moisture Free	Moisture and Ash Free
Moisture	3.5	-	-
Ash	5.0	5.18	-
Volatile Matter	36.14	37.45	39.5
Fixed Carbon	55.36	57.37	60.5
	100.00	100.00	100.0
Sulphur	0.92	0.95	1.0
Hydrogen	5.12	5.31	5.6
Carbon	77.13	79.93	84.3
Nitrogen	1.65	1.71	1.8
Oxygen	6.68	6.92	7.3
	91.50	94.82	100.0
Btu per lb	13725	14225	15000

AVERAGE ANALYSIS OF A WESTERN KENTUCKY BITUMINOUS COAL

	As Received	Moisture Free	Moisture and Ash Free
Moisture	7.5	-	-
Ash	9.0	9.73	-
Volatile Matter	36.74	39.72	44.0
Fixed Carbon	46.76	50.55	56.0
	100.00	100.00	100.0
Sulphur	2.92	3.16	3.5
Hydrogen	4.50	4.87	5.4
Carbon	67.24	72.68	80.5
Nitrogen	1.50	1.62	1.8
Oxygen	7.34	7.94	8.8
	83.50	90.27	100.0
Btu per lb	12110	13090	14500

AVERAGE ANALYSIS OF AN EASTERN KENTUCKY CANNEL COAL

	As Received	Moisture Free	Moisture and Ash Free
Moisture	2.0	-	-
Ash	9.0	9.18	-
Volatile Matter	48.95	49.95	55.0
Fixed Carbon	40.05	40.87	45.0
	100.00	100.00	100.0
Sulphur	1.07	1.09	1.2
Hydrogen	6.23	6.36	7.0
Carbon	73.51	75.01	82.6
Nitrogen	1.25	1.27	1.4
Oxygen	6.94	7.08	7.8
	89.00	90.81	100.0
Btu per lb	13975	14260	15700

The two principal coal seams, known as No. 9 and No. 11 are in the Mulford Formation. These two seams furnish nearly all of the output of the Western Kentucky Field.

Small deposits of cannel coal occur in several counties of the Eastern area. Morgan, Johnson, Bell, Carter and Floyd counties have such deposits but the total production of cannel coal is relatively small.

To the above variety of geological names are added numberless trade names that give the impression that every mine and mining district produces a different and distinct variety of coal.

Fortunately, the only marked difference in the coals of Kentucky is actually in the Eastern and Western separation, and the great variety of names does not indicate a great variety of coals. With the exception of the cannel coals, most of the Eastern field coals are similar, both in composition and character. Likewise, the fact that a coal comes from Western Kentucky is a fair classification of its composition and characteristics.

The cannel coals of the Eastern field are readily distinquished by their high hydrogen content, physical appearance and combustion characteristics.

Characteristics of Eastern Kentucky Coals

The Eastern coals from Harlan, Perry, Pike, Letcher, Floyd, Bell and Knox counties are high volatile, low ash, low moisture, low sulphur and high heat value coals. They are used largely for coke and gas making. Their ash fuses at temperatures from 2400 to 2900 F. These coals are fairly hard and stand shipment well and, although too valuable for railroad use, are used to some extent as domestic fuel. Similar coals are mined in the adjacent states of Virginia and West Virginia but the Kentucky coals are generally harder than their more Eastern equivalents. Some Eastern Kentucky coals, notably the Harlan, Miller's Creek and Hazard seams, are called block and splint coals. These terms are names descriptive of the physical appearance of the coal. A block coal has lines of cleavage such that it may be mined out in large blocks. The blocks stand handling well and often appear in the market in cubes of five to ten inches with smooth flat surfaces. The splint coals, on the other hand, have lines of cleavage such that they break more easily in a vertical direction and the coal, as mined, resembles splintered posts. Other Eastern Kentucky coals, as for example, the Elkhorn, mine in hard smooth lumps of irregular size and shape and are ideal for domestic use.

The cannel coals have a very characteristic fracture similar to that of broken pitch. Cannel coal is a dull black when broken but its surface may be polished to give a high lustre. These coals have a high gas and oil content and splinters of the coal may be ignited with a match. The term "cannel coal" is a derivation of an old term "candle coal."

Western Kentucky coals are similar to the coals of Illinois and Indiana. They are high in volatile, sulphur and ash. They are generally classed as free burning but will form coke. Their high volatile content makes them desirable as gas producer coals but the bulk of the western production is used for railroad, steam and domestic fuel. The Western Kentucky coals are not as hard as the Eastern Kentucky coals and do not stand shipment well. Their fracture is irregular and their lines of cleavage, formed by thin laminations of clay or mineral matter, tend to weaken on weathering.

The Eastern Kentucky coals are probably best burned on underfeed stokers. They may be burned in pulverized form but are harder to pulverize than most Eastern bituminous coals. The Western coals can be burned either on a traveling grate stoker, underfeed stoker or in pulverized form.

Uniformity of Moisture and Ash

As explained in previous articles, moisture- and ash-free analyses are fairly uniform for coals from the same area and seam. Typical individual analyses of coal from the Harlan bed in Harlan County and from the No. 9 bed in Muhlenberg County are given in Table IV and show the general difference in the analyses of Eastern and Western Kentucky coals. In Table V is given average analyses of coals from the principal counties of the coal producing regions of Eastern and Western Kentucky. Although more than one seam may contribute to the production of a county, the similarity in the analyses does not warrant the determination of average analyses for both counties and seams. The counties in Table V are listed in order of their relative production and the analyses for Harlan and Perry Counties and for Muhlenberg and Hopkins Counties represent, respectively, typical analyses of Eastern and Western Kentucky coals.

In Table VI are given proximate analyses of typical Kentucky coals as given in a Keystone Coal Catalogue. These analyses are for the principal seams and beds and it may be noted that some of the analyses are for the same seam though given under different names. For example, Hazard No. 4, Fireclay and Dean are different names for the Upper Mercer seam. Positive identification of the various seams and correlation of their local names is difficult and apparent inconsistencies exist in the literature. From an analytical standpoint however, occasional misnomenclature is not serious because of the uniformity in the composition of the coals.

In the absence of information other than that a coal is a Kentucky cannel, an Eastern Kentucky or a Western Kentucky coal, the average analyses set up in Table VII may be used without serious error. These analyses are set up for an average moisture and ash content for mine samples and therefore the "as received" analysis may not be correct for a delivered coal. Usually the moisture and ash content for a coal are available or may be readily determined in a small laboratory and in such cases, the "as received" and "dry" analyses may be calculated from the moisture- and ash-free averages in the usual manner. Formulas and conversion charts for these calculations are given in previous articles of this series on coal analyses.

The Mississippi Valley Commission, a sub-division of the National Resources Board, has recently made its report to the President in which it recommends a billion dollar program, to be spent over a twenty-year period for the construction of 500 dams for power and flood control. It proposes to link public and private power plants into a huge system covering the states drained by the Mississippi and its tributaries.

Measuring Cinder Returned to Stoker Clinker Pit

The installation of boiler-hopper drain lines in boilers at Hudson Avenue Station is shown to aid the boiler cleaning problem and yield the return of heating value of the cinders. Tests were run at fuel burning rates of 53 and 41 lb of coal per square foot per hour, corresponding to 375,000 and 300,000 lb of steam per hour, respectively, and indicated that about 40 per cent of the cinder is removed from the gas at the boiler hopper.

THE most recent installation of bent-tube boilers in the Hudson Avenue Station, Brooklyn, is provided with soot hoppers at the bottom of the second gas pass, located in the rear of the boiler mud drum. These hoppers are provided on this type of boiler so that the accumulation of soot, cinder and scale, which is deposited can be removed from the proximity of the lower drum. On this particular installation, the hoppers were not initially connected to any external piping upon start of operation, pending experience with the units and further consideration of means of handling the deposit.

For temporary drainage when cleaning the hoppers during boiler outage, flexible hose entering the furnace through the rear doors was used. A permanent system of piping designed along similar lines was later installed, connecting to the bottoms of the hoppers and entering the furnace between the fin tubes of the furnace rear wall at a proper elevation and with the necessary slope to convey the cinder. It was necessary to use a specially designed flap valve in the line to assist proper functioning in normal operation, because of the higher draft condition existing at the upper end of the line, which tends to cause upward flow of air from the furnace.

This drain system functioned in a very satisfactory manner at moderate ratings, and with some additional manual attendance, its operation was continued to the higher outputs. At the higher ratings the 4-in. lines from the four hoppers appeared to run full almost continuously, and the amount of cinder returned by this very simple form of cinder catcher was considerable.

The piling up of the cinder under the discharge spouts could be observed in operation, and it was necessary to install a small connection to the forced-draft duct which discharged under each spout and distributed the cinder over the ashpit.

To obtain a measure of the effectiveness of this system, answers to the following questions were sought.

1. What proportion of the total cinder released from the stoker was trapped in these hoppers and returned to the ashpit?
2. Was the returned cinder burned in the ashpit, or was it discharged without burning, serving to increase the combustible in refuse loss?

This system had been in operation during a series of efficiency and heat-balance tests on the boiler and stoker unit, and the combustible in refuse loss, determined by sampling the ash and refuse below the clinker rolls, had averaged less than one-half of one per cent. On this basis it was believed that whatever cinder was returned to the pit was quite completely burned, since this figure is a low value for the ashpit loss, even when no cinder is returned. The cinder loss and combustible in refuse loss data from this test are shown in Fig. 1. The cinder loss in this figure includes only that measured leaving the boiler at the flue.

It had been recognized that a certain amount of "recirculation" of cinder might exist, that is, cinder returned to the ashpit might be caught in the furnace gas flow, recirculated through the boiler, redeposited in the boiler hopper and returned through the drain line, thus augmenting the flow through this line. Because of the relative quietness of the ashpit zone, it was not believed this effect was very great. An additional series of tests was arranged to determine among other things, the extent of the "recirculation."

The series of special tests to determine quantitative data on the cinder distribution covered three cases, illustrated in the three boiler views, Figs. 2 to 4, with conditions as follows:

Fig. 2—Cinder from boiler hoppers returned to ashpit, as during heat-balance tests.

Fig. 3—Cinder from boiler hoppers drained separately and disposed outside the furnace.

Fig. 4—Boiler hoppers blanked off, and cinder allowed to build up in the hoppers to equilibrium, thenceforth leaving by means of the boiler flue outlet.

In all three cases, the cinder still remaining in the boiler gases after leaving the boiler was measured by the sampling method, just previous to reaching the inlet of the wet-type cinder catchers located overhead. Twelve sampling tubes were used across the flue, in a manner similar to that used in obtaining the data for Fig. 1. In Case 1 (Fig. 2), the rate of return of cinder from the hopper to the ashpit was determined by diverting the flow from each hopper separately for five-minute periods and measuring the flow rate. Two measurements for each hopper were taken for each five-hour test.

A five-hour test was run at each of two ratings for each of the three cases mentioned. Each five-hour test was separately computed in two parts to obtain a check on

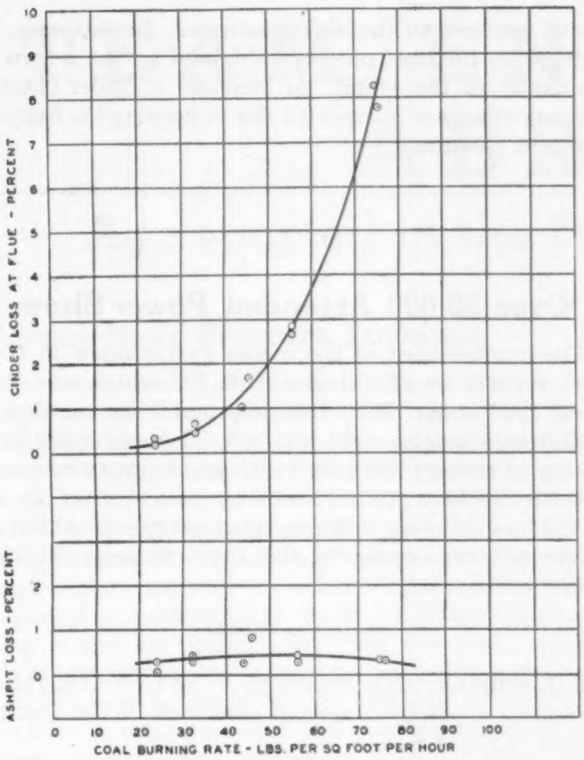


Fig. 1—Cinder and combustible from refuse loss

the steadiness of conditions. The two ratings chosen were high enough to give appreciable quantities of cinder to measure, and low enough so that stable operation of the stoker could be expected, giving consistent results. Incidently, at the two ratings selected, 375,000 lb of steam per hour, and 300,000 lb of steam per hour, the slope of the cinder production curve is such that the ratio of total cinder quantities is about two to one. The coal burning rates at these two boiler outputs are approximately 53 and 41 lb per square foot per hour, respectively.

The results of the tests showing cinder quantities is shown in the accompanying tabulation. This indicates that the amount of cinder leaving the boiler at the flue is about the same for Cases 1 and 2. The greater amount removed at the boiler hoppers in Case 1 compared with Case 2 indicates recirculation. The data of Case 2 are

TABULATION OF CINDER QUANTITIES EXPRESSED AS POUNDS PER HOUR

		Case 1	Case 2	Case 3 First Tests	Case 3 Check Test
Steam Flow 300,000 Pounds Per Hour	Cinder at Flue	980	890	1100*	
	Cinder at Hoppers	815	535	0	
			1425		
Steam Flow 375,000 Pounds Per Hour	Cinder at Flue	1850	1920	2250*	2480
	Cinder at hoppers	1600	1280	0	0
			3200		

* Tests conducted with 18% excess air, other runs with 30% excess air.

probably the most accurate measure of the total cinder leaving the stoker, since all of the cinder leaves the boiler in one of the two paths and that leaving at the hoppers was weighed in its entirety. The results of tests for Case 3, show cinder readings considerably lower than would be expected from the results of the previous tests. In investigating the discrepancy, it was found that the building up of cinder in the hopper to obtain conditions for Case 3 had changed the resistance characteristics of the boiler so that the boiler flowmeters were adjusted to give an excess air of 18 per cent instead of 30 per cent as maintained for the previous tests. With the meter

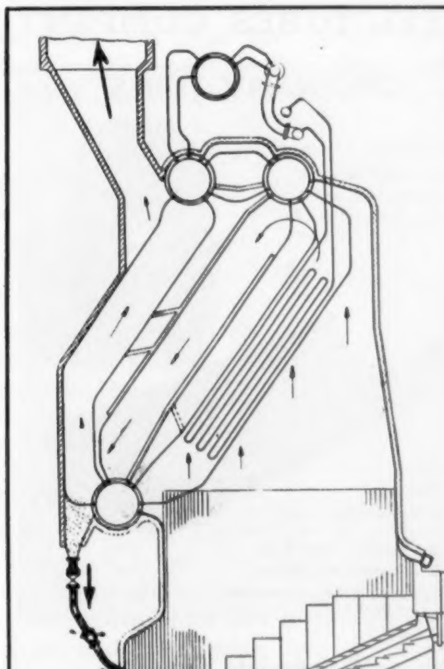


Fig. 2—Cinder returned to ash pit

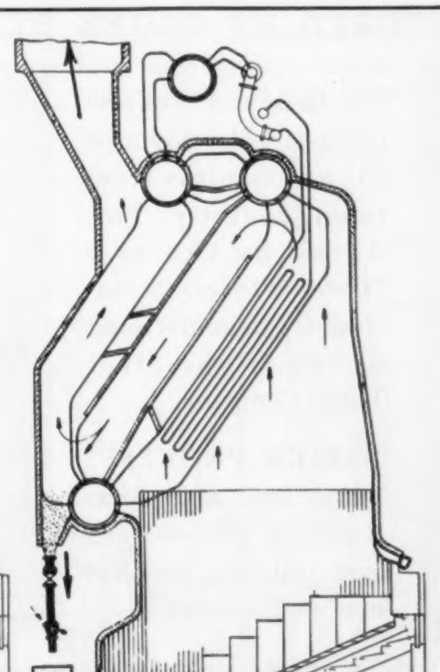


Fig. 3—Cinder drained outside furnace

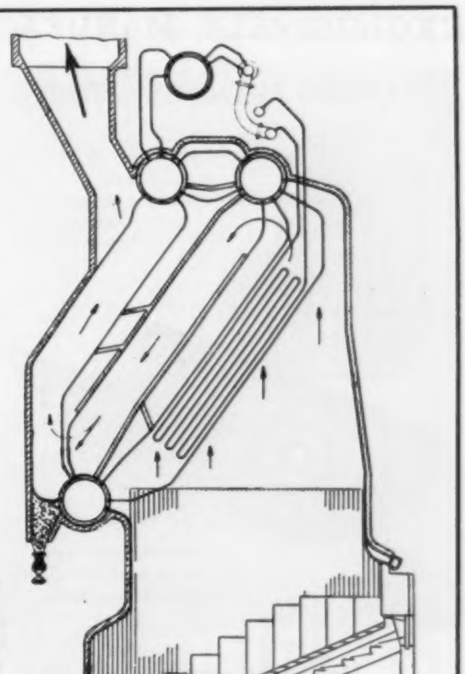


Fig. 4—Cinder allowed to build up

readjusted and checked, an additional run was made at the 375,000 lb per hour rating with 30 per cent excess air. This resulted in somewhat higher cinder loss than previously, as would be expected for higher air flow through the stoker, but the value was still below the total cinder amount indicated by a total of the flue cinder and hopper cinder in Case 2.

The only remaining condition which explains the difference between the results of Case 2 and Case 3, is that some burning of cinder took place in the hoppers during the conduct of the tests for Case 3, as evidenced by the formation of clinker. It appears that a proportion of the cinder became trapped on the surface of the accumulation in the boiler hoppers and burned there, reducing the amount of cinder going to the flue in this form.

The conclusion of this investigation is that at the ratings investigated, about 40 per cent of the cinder generated on the stoker is removed from the gas at the boiler hopper, which becomes, in effect, a "primary" cinder catcher, operating to remove the coarser cinder at this point. This is returned to the ashpit and burned with a high degree of completeness, as evidenced by the low percentage of combustible in the ashpit refuse.

The relative shortness of the piping connection and the absence of accessory equipment make this system attractive as a means of keeping the hoppers drained. Further work is under way to make the capacity of these lines adequate for operation at the higher ratings, without excessive manual attention. A system of drain lines with flap valves is being installed on another group of four boilers, connecting the hoppers of the dry type cinder catchers to the stoker ashpits. In this case, in addition to the heat recovery obtained by the return of the cinder to the ashpit, an increase in cinder catcher recovery efficiency is expected due to keeping the hoppers empty at all times.

Over 36,000 Attended Power Show

The management of the recent Power Show in New York reports an attendance of 36,798 which was only about 1200 under 1932; this despite a fewer number of exhibitors which for 1934 was 245. A particularly high quality of visitors was noted with an obvious absence of curiosity seekers. The character of inquiries as reported by exhibitors indicated that many were thinking in line with the keynote of this show, namely, "cutting power service costs."

L. J. Schrenk, Superintendent of the Detroit Lighting Commission has been elected chairman of the Detroit Section of the A.S.M.E.

H. F. Reck has been given general supervision of all the power plants of the General Motors Corporation. His headquarters are in Detroit.

STEAM ENGINEERING ABROAD

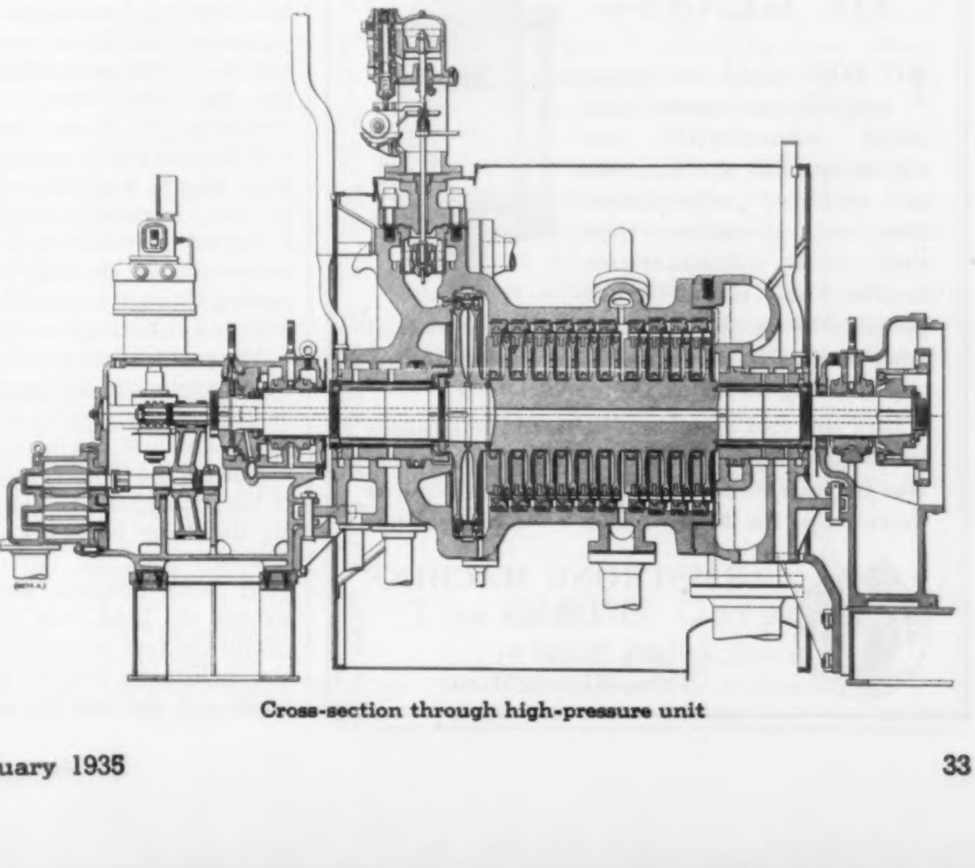
As reported in the foreign technical press

Trebovice High-Pressure Turbines

In its description of the Trebovice Power Station in Silesia, Czechoslovakia, *Engineering* (London) of November 30 gives details of the high-pressure turbines which operate under a pressure of 1800 lb per sq in. and 930 F. These are three-cylinder tandem machines rated at 30,000 kva and running at 3000 rpm. The high-pressure element has a Curtis stage and ten impulse stages, the two Curtis wheels being carried on the shaft by means of supporting rings, while the disks of the remaining stages are forged solid with the shaft. The wheels are pressed on the supporting rings with a certain amount of stress between the hub and ring, so that an elastic joint is obtained. The shaft seating is formed in five steps each slightly smaller in diameter than the next which facilitates assembly or removal of the wheels. The Curtis wheels and the shaft were forged from steel selected from the standpoint of creep limit rather than yield point in view of the high temperatures involved and both the wheels and the shaft were annealed several times during manufacture. The moving blades of the Curtis stage are of Durehete steel. These are subjected to high stresses while the heat drop over the Curtis wheel is greatly increased at small loads owing to the group type regulation whereby the admission of steam is restricted to a small part of the circumference of the wheel. The blades are machined from the solid piece and have an inverted T at the base which fits into a groove in the rim. While the guide blades of the Curtis stage are of Durehete steel, those of the other stages are of nickel steel.

The high-pressure casing is made from two molybdenum steel castings, ground and carefully faced, the two sections being made horizontally on the center line. A special arrangement has been employed for bolting together these two sections, known as the Kieswetter connection. In this the bolt heads are in the form of flat plates which bolt together, end to end, when the bolts are in position in the flanges, holes or half holes being made at the ends of the plates. Adjacent bolts have their heads on opposite sides of the flanges, so that the shank of every bolt passes through the hole formed by the heads of the bolts on the two sides of it. This arrangement permits close pitching yet allows ample room for the nuts.

The intermediate- and low-pressure elements of the turbines are of more or less standard design.



Cross-section through high-pressure unit

Glass Silk Insulation

During the war when Germany was faced with a shortage of asbestos, glass silk was developed as a substitute. This is produced from glass melted in an electric furnace and forced through minute apertures. Subsequently it found certain applications both abroad and in the United States and its production was begun in England in 1930. Its application as insulation in power plant work in that country is, however, more recent and it is now used quite extensively for lagging boilers, accumulators, heaters, engine cylinders and for piping insulation. It is especially adapted to marine use where vibration is likely to be severe and has consequently found wide use in that field. Tests made at the National Physical Laboratory (England) have shown that with a density of 3.4 lb per cu ft the thermal conductivity between a cold face temperature of 1 C and 15 C was 0.28 Btu per sq ft per hr per deg F per 1 in. thickness. It is said to compare favorably with 85 per cent magnesia.—*The Fuel Economist* (London), November 1934.

More Velox Boiler Tests

A 26,500 lb per hr Velox boiler has been in service at Mondeville, France since November 1933, operating at 455 lb pressure and 800 F steam temperature. According to the *Association Normande des Proprietaires d'-appariels à Vapeur,* which conducted official tests on the unit, the boiler efficiency based on gross calorific value was 91.9 per cent, or 87.8 per cent including all auxiliary losses excepting the boiler feed pump and based on the net calorific value of the gas.

Pulverized Coal for Small Furnaces

The Fuel Research Board (Great Britain) is conducting experiments on pulverized coal with the object of developing methods whereby it can be burned successfully in boilers having small combustion spaces such as the Lancashire type. It has been found that when the coal contains less than twenty per cent volatile difficulties are encountered. Several types of burners are being studied as to their flexibility and further studies are being conducted on colloidal mixtures of oil and pulverized coal.

Lessening Maintenance on Traveling Grates

An interesting account of investigations in controlling the temperature of traveling grate stokers as conducted by Messrs. Maughan, Spaulding and Thornton, is contained in the October *Journal of the Institute of Fuel* (London).

The growing practice of cleaning coal at the collieries has been found to result in higher maintenance of traveling grate stokers due to overheating of the links. After a series of tests with different grades of coal, in which the fuel bed temperature on the links was measured by thermocouples, it was found that the zone in which the volatiles are freed, namely, the first sixty per cent of the grate length, was relatively cool, whereas the last forty per cent, representing the zone in which the fixed carbon is burned in contact with the links, was very hot. The temperature of the links rises until the heat lost to the air passing through is equal to the heat taken up by contact with and radiation from the hot coke.

The problem resolved into (1) increasing the heat lost by convection to the incoming air, and (2) reducing the heat gained by contact with and radiation from the fuel bed. The first can be accomplished to some extent by increasing the burning rate and lowering the temperature of the preheated air. The second was effected by dividing the stoker hopper horizontally into upper and lower compartments, the latter containing crushed ashes or other inert material which when fed onto the grate screens the links from the heat of the hot coke. To obtain the best results this layer of ash should be about one inch thick, contain a high percentage of inert material, and the finer the ash the lower the link tempera-

ture. The authors found that with the links thus protected an air preheat temperature of 570 F might be safely used on traveling grates so long as no difficulty is encountered with softening of the bottom layers of the coal.

High-Pressure Steam Plants

The Engineer (London) of Nov. 9 contains a partial list of high-pressure steam plants throughout the various countries, of which twenty-two operate at over 1100 lb per sq in. Fourteen of these are in the United States, two in England, one in Russia, one in Germany and three in Czechoslovakia. The three highest actual operating pressures are Loeffler boiler installations, that of the new Soviet power station in Moscow being 1900 lb per sq in. and 932 F. Next comes the new Trebovice power station in Czechoslovakia which operates at 1845 lb per sq in. and 832 F. The Grube Isle Station in Germany is listed at 1633 lb per sq in., 887 F and the Mannheim Station at 1420 lb per sq in. and 878 F. No mention is made of the Benson boiler installations which although designed for the critical pressures are operated much below that point.

German Industrial Works Employs Superimposed High Pressure Plant

A recent application of a Loeffler boiler to a German industrial plant is described in the December issue of *The Steam Engineer* (London). This is the Hoechst Works of the Farbenindustrie A.G. in which the boiler will be capable of producing 100,000 lb of steam per hr at 1706 lb pressure and 932 F steam temperature. It will supply a high-pressure turbine exhausting at 213 lb to three back-pressure turbines exhausting at 45 lb to process. The exhaust pressure of the high-pressure turbine, namely 213 lb, corresponds to the steam pressure of the old boilers in the plant. The steam from the new boiler will cover the base load process requirements, leaving the peak load requirements to be made up by the old boiler plant. The new boiler will have a chain grate stoker.

Hams Hall Extension

Hams Hall, one of the well-known English power stations, is to be extended by the addition of five 300,000 lb per hr maximum capacity boilers operating at 375 lb pressure and 730 F steam temperature. Three of these units will be fired by pulverized coal and two by stokers of the chain-grate type. There will be five unit mills per boiler and part of the preheated air will be employed for mill drying. No economizers will be used. A dust collecting system will be installed. It is interesting to note that although the operating pressure is only 375 lb the steam drums will be of solid forged construction with swaged ends.

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Belting and Packing

A valuable addition to the reference library of engineers, purchasing agents, and other factory executives is the new Mechanical Rubber Goods Catalog of the New York Belting and Packing Company which provides a fund of practical information about hose, belting, packing and miscellaneous mechanical rubber products. Illustrations and complete information are given about each product and diagrammatic drawings outline various applications. There are tables giving belt speeds, pressures and temperatures, carrying capacities, and dimensions. Numerous formulas on everyday problems are presented with practical examples of their usage.

Blowers

Bulletin 22:23-B10 has been issued by Roots-Connersville Blower Corp., Connersville, Ind., illustrating and describing its standard and heavy duty types of blowers. The first few pages are devoted to a general discussion of the inherent characteristics and the operating principle of the rotary positive type of blower. This is followed by typical installation views and descriptions of services in which rotary positive blowers are widely used, such as: agitation and aeration, combustion service, supercharging and scavenging, vacuum processes, gray iron foundries, sewage disposal plants, pneumatic conveying, mining and smelting, tunnel ventilation, blowing water gas sets, etc. The involute impeller design is suitable for pressures up to 10 lb gage in the single-stage units, and up to 20 lb gage in the compound arrangement. Type 'SD' standard duty blowers are designed for low or intermittent pressure service, and Type 'HD' heavy duty blowers for continuous service at higher pressures.

Centrifugal Pumps

An advanced development of its two-stage Monobloc centrifugal pump is featured in a recent bulletin issued by Worthington Pump and Machinery Corporation, Harrison, N. J. This pump has been designed especially for high efficiency and low power requirements and is intended for services requiring relatively small capacity and medium discharge head. It is compact and of unit construction in which the two enclosed type impellers are cast back-to-back, thus making the overhung weight no greater than on a single-stage pump. It can be installed either horizontally or vertically.

Coal and Ash Handling

C. O. Bartlett & Snow Company, Cleveland, Ohio, has just issued a 44-page catalog covering its complete line of coal and ash handling equipment. Following a brief discussion of the development of the company's centralized coal and ash-handling system, a table is provided to assist engineers in determining sizes and capacities of equipment required for various sizes of plants, based on rated horsepower. Typical plant layouts are suggested and diagrammed. Details are provided as to track hoppers, weigh-type skip bucket loading gates, skip hoist buckets, skip hoist runways, head frames, etc. Two pages are devoted to a discussion of hoist engines and hourly capacities of skip buckets. Operation of the electrical control is described. Advantages offered by cylindrical and suspension type coal bunkers are discussed and a table provided in which are shown popular sizes of bunkers that can be furnished quickly from shop drawings already prepared. The ash hoppers themselves and accessory equipment such as quenchers, soot chutes, ash gates, ash cars, track and turntables are also included. Numerous photographs and blueprints are reproduced in the bulletin.

Combustion Control

The Brooke system of balanced combustion control is described in a new bulletin by the Brooke Engineering Company, Philadelphia. This is a "fuel-air-ratio" control and is basically a system wherein a master fluid pressure is used responsive to changes in plant steam pressure. Individual regulators are employed on each stoker or pulverizer and individual air regulators at each damper or fan to control the quantity of air delivered to each boiler. The ratio of fuel to air is automatically maintained in balance irrespective of load changes.

Deaerating Heaters

The elimination of oxygen in solution by deaeration to prevent corrosion of piping economizers, boilers and steam turbines is constructively discussed in a 24-page bulletin (No. 700) recently issued by the Cochrane Corporation, Philadelphia. Among the deaerating heaters and combinations described in the bulletin are, direct-contact heaters of the tray type, direct-contact heaters with jet sprays and tray stacks or with steam atomizers for marine work, surface type heaters, direct-contact deaerating heaters supplemented by surface or jet type heat exchangers, convertible direct-contact heaters, deaerating metering heaters, direct-contact or surface type heaters combined with surge or storage tanks, and direct-contact deaerating heaters combined with hot process softeners. The bulletin is well illustrated.

Draft Gages

Bulletin No. 2018 has just been issued by The Hays Corporation, Michigan City, Ind., covering its new line of "Draftrol" electric contact gages for indicating and controlling draft, pressure and differential draft or pressure.

Refractories

Harbison - Walker Refractories Company, has issued a folder entitled "Insulate With Safety at Any Temperature." It emphasizes the importance of the selection of the proper refractory as well as the proper insulating material for any insulated furnace construction and describes both insulating brick and light weight brick and their applications. The information given applies to three types of brick, namely, HW-777, a diatomaceous earth brick possessing unusual mechanical strength for brick of that type and a safe working temperature of 2000 F; HW-111 a light-weight brick, made from flint fire clay, which will withstand temperatures up to 2500 F; and HW-444, a light-weight silica brick which may be used with safety at temperatures up to 2900 F without danger of shrinkage or loss in insulating value.

The light weight brick are used as an insulating backing where the interface temperature between the refractory furnace lining and the insulation exceeds the safe working temperature of the usual type of insulating brick. They are also used as the refractory lining in furnaces where they will not be subjected to abrasion or to corrosive action of slags.

Steam Turbines

General Electric Company has just issued three new bulletins covering turbines for mechanical drive. One covers single-stage noncondensing turbines in sizes of 40 to 400 hp for steam pressures up to 450 lb and temperatures up to 750 F; these units being adapted to drive fans, pumps, compressors and pulverizers. The second deals with multi-stage condensing or noncondensing units of 100 to 2000 hp, equipped with an oil relay governor and likewise built for pressures up to 450 lb and 750 F steam temperature. The third describes a line of multi-stage turbines to run either condensing or noncondensing with steam extraction or mixed pressure operation and equipped with a multi-part valve gear. These are built in sizes of 100 to 2000 hp and for steam conditions of 450 lb and 750 F temperature.

Valves

The Edward Valve & Manufacturing Company, East Chicago, Indiana, has just issued catalog No. 11-G4 describing forged-steel specialties. Featured are gage valves, straight-through valves, strainers, relief valves, special valves for turbine oil lines and small forged-steel stop-check valves.

Water Analysis

W. H. & L. D. Betz, chemical engineers of Philadelphia, have issued an 18-page booklet containing a series of articles that have appeared in The Betz Indicator, dealing with chemical analysis of water, turbidity, suspended matter, hardness, pH values, what is indicated by magnesium, sulphates, chlorides, iron, surface tension, sulphate-carbonate ratio, etc.

NOTICE

Manufacturers are requested to send copies of their new catalog and bulletins for reviews on this page. Address copies of your new literature to

COMBUSTION
200 Madison Ave., New York

NEW EQUIPMENT

of interest to steam plant engineers

New Electric Flow Meter

The Cochrane electric flow meter, which is here illustrated, is distinguished by the fact that the power for the operation of the pointer, pen and integrator is the same throughout the entire range of measurement. The pressure differential caused by flow through the orifice or nozzle is not required to move the registering mechanism, which is done instead by external power from an electric motor, the application of which is controlled by a sensitive relay.

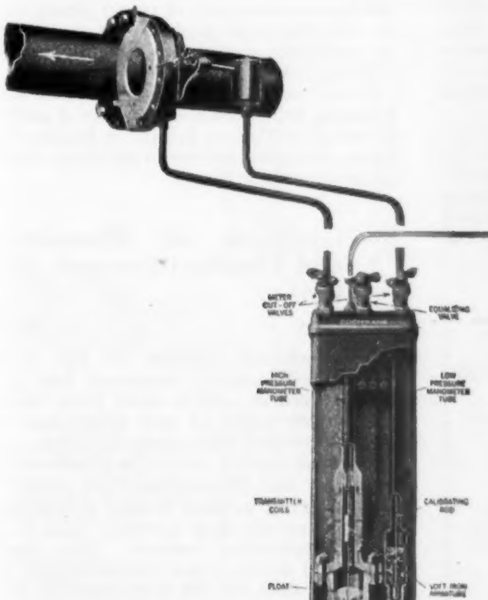
Flow through the pipe line causes a float carrying a soft iron armature and resting on the mercury in a U-tube to be displaced a certain distance and this displacement is balanced electrically by shifting a similar armature in the recorder, the two armatures being surrounded by the inductance coils of a bridge circuit traversed by an alternating current. Unbalance of the circuit deflects the boom of a sensitive galvanometer, which directs the application of power to shift the recorder armature until the galvanometer boom returns to neutral. The value recorded is that at which balance is attained, regardless of the direction from which the value has been approached and there is no lag caused by friction or other non-reversible forces. The circuits and galvanometer are so proportioned that a displacement of the transmitter armature of less than 0.001 in. causes the galvanometer boom to deflect and is, therefore, registered by the recorder, corresponding in the usual installation to but 0.01 of one per cent change in rate of flow at mid-scale.

As no current flows through the galvanometer circuit at the moment of measurement, accuracy is not influenced by variations in electrical resistance of conductors, by variations in contact resistance, by changes in length of leads, by inequalities in winding, by variations in strength of magnetic field, etc.

The angle through which the relay shaft is turned at each adjustment is in direct proportion to the deflection of the galvanometer boom, and hence to the degree of unbalance of the circuit. Long steps and rapid adjustment are thus made when the circuit is greatly unbalanced, but only short, precise steps are taken as balance is approached, consequently the instrument can follow quick changes in rate of flow without over-shooting and without sacrifice of accuracy in the final adjustment.

The movement of the relay unit shaft is transmitted to the receiver armature by a cam, which is so shaped that shifting of the receiver armature into correspondence with the transmitter armature is always accompanied by rotation of the relay unit shaft through an angle proportional to the change in rate of flow.

Integration of the flow is performed at least once per minute, appropriate gear ratios being selected so that the integrator multiplier will be in integral terms for different meter capacities. The figures on the counting train read directly, just as do those of an automobile mileage recorder.



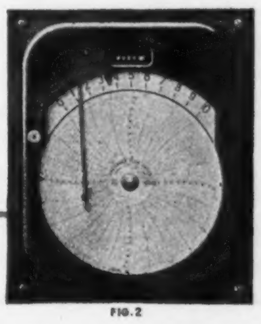


FIG. 2

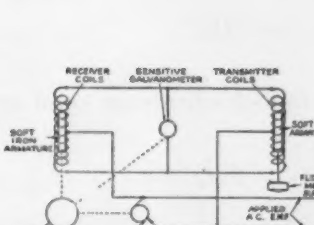


FIG. 1

High Temperature Soot-Blower Element

There is a constant need for a soot blower element for use in high temperatures above 2100 F. After research and experimentation, the Bayer Company of St. Louis, developed a soot-blower element possessing the essential properties for this severe service. This alloy, known as "Chronilloy," is an alloy of chromium and nickel with other elements added, making a total alloy content running from 40 to 80 per cent, to give it the required properties. The alloy is exceptionally tough and strong at elevated temperatures. The elements are made with an exceptionally heavy wall, 20 per cent heavier than ordinary extra heavy alloy tubing, so that they resist warping. Chronilloy elements are furnished in two grades, depending upon service conditions and are made in either $1^1/_2$ in. or 2 in. sizes.

Mechanical Flow Meter

The new mechanical flow meter of Republic Flow Meters Co., Chicago, is a simple flow metering device, designed primarily for those installations where remote registration is not required. The entire instrument is assembled on a steel panel which can be easily mounted on a pipe, wall or table. The reading instruments, indicator, recorder and integrator are calibrated to read or record in terms of flow. The recorder can be had separately or in combination with the integrator or indicator.

The integrator is of the cyclometer type, registering in pounds or gallons, the total flow through the line. It is driven by a synchronous motor which at intervals of 15 sec, adds on the counter the flow through the pipe during that period. The meter body is a simple "U" tube, balancing a column of mercury against the differential pressure caused by the flow of a fluid through an orifice installed in the line. The rise and fall of the mercury positions a large float located in the high-pressure chamber. The float in turn positions the recorder pen arm in direct relation to the changes in mercury level. A check valve has been provided to prevent sudden surges in the line from blowing the mercury out of the meter body. This valve is held open by the mercury in the high-pressure chamber. As the flow reaches the maximum capacity for which the meter was designed, the mercury is forced out of the high-pressure chamber permitting the valve to seat itself, thus preventing the mercury from being blown out of the low-pressure side of the "U" tube. When the flow again drops to within the range of the meter, the valve immediately unseats, and the meter goes back into operation.

The meter body is so designed that the range can be easily and conveniently changed by merely replacing the range tube with a tube of proper size. The range tubes are interchangeable and made in three sizes corresponding to low, medium and high differential pressures.

ENGINEERING BOOKS

1—The Engine Indicator. Its Design, Theory and Special Applications

By K. J. DeJurasz

235 pages 5½ × 8½ $3.75

The Engine Indicator by K. J. DeJurasz presents the history, theory and construction of the many forms of the pressure indicator from its inception to the present day. It contains much valuable information not only for engineers in power plants, pumping stations, engine factories and automotive and aeronautical research laboratories but also for all engineers who have to investigate *forces* and *motions*, and particularly for engineers who may not be principally interested in engines but who are concerned with *variable pressures*.

The price includes a year's subscription to the magazine *Instruments*.

2—Principles of Direct Current Machines (Fourth Edition)

By Alexander S. Langsdorf

586 pages 5½ × 8 $4.50

The revision of this well-known textbook brings all the material up to date and presents new material on equalizer connections in multiple windings; on constructions of generator and motor characteristics; on motor starting devices and rheostats, and on the mechanics of motor acceleration and retardation.

3—Bailey's Handbook of Universal Questions and Answers (Sixth Edition)

264 pages 4¾ × 6½ Price $2.00

The questions and answers contained in this Handbook are those that have been universally asked by examining boards and were compiled from over four hundred examination papers, including tests for firemen, engineers and boiler inspectors. It gives information on the subjects of boilers, pumps, fuel consumption, valves, heating systems, engines, etc., and will be of assistance not only to those studying for any grade of license in this country or in Canada but also to the practical engineer and fireman.

The author, A. R. Bailey, is intimately acquainted with the needs of practical engineers and firemen and of candidates for licenses, having served as engineer and boiler inspector in the states of Massachusetts, Ohio, Pennsylvania and Michigan, and as safety engineer for the Lincoln Motor Company, Detroit. The sixth edition of this book, recently published, has been brought thoroughly up-to-date.

4—Diesel Engineering Handbook

Edited by L. H. Morrison and T. A. Burdick

320 pages 9 × 12 Price $5.00

This is the seventh edition of this handbook which brings the reader up to date on diesel practice in this country as pertaining to stationary practice, automotive and railway applications. Following a basic discussion of the diesel cycle, the principal types and makes of engines are described, and chapters are devoted to various auxiliaries, to lubrication, cooling, installation and starting. Maintenance and inspection schedules are included, as well as a set of stations logs for keeping plant records.

The book is both educational and informative and should prove of great assistance to men operating diesel plants or steam plants that include supplementary diesel service.

5—Specifications and Tests for Coal and Coke

108 pages Price $1.00

For the first time, a compilation of all the standard and tentative specifications and tests for coal and coke, as issued by the American Society for Testing Materials, has been published. This includes five specifications, thirteen methods of test and the standard definitions of terms relating to coal and coke.

Foundry coke and gas and coking coals are covered by specifications—and to make the pamphlet complete, the recently approved requirements for classification of coal by rank and by grade, developed by the Sectional Committee on Classification of Coals, are included.

6—Elements of Heat-Power Engineering—Parts II and III (Third Edition)

By W. N. Barnard, F. O. Ellenwood and C. F. Hirshfeld

Part II: 871 pages 6 × 9 Price $5.50
Part III: 415 pages 6 × 9 Price $4.50

This work is in three volumes. Part I covering "Thermodynamics" was completely rewritten in 1926. Parts II and III, covering, respectively, "Steam Generating Apparatus and Prime Movers, Fuels, Combustion and Heat Transmission" and "Auxiliary Equipment, Plant Ensemble, Air Conditioning and Refrigeration," were completely rewritten in 1933 to form the third edition. In doing this the books have been brought in line with current practice and offer an excellent combination of underlying theory and its reduction to practice. The descriptive range and performance of equipment of different types and makes are unusually complete, typical installations involving a variety of arrangements are included, and the economics of power plant design are discussed.

7—Power Supply Economics

By Joel D. Justin and William G. Mervine

276 pages 6 × 9 $3.50

This book was written primarily for the executives and engineers of power companies and industrial concerns who may, in greater or lesser degree, be charged with the responsibility of maintaining or providing a dependable power supply.

Although the book treats of the broad general principles of the economics of power supply and does not go into technical details, the authors believe that engineers charged with the investigation, design and construction of power plants and the utilization of such plants to obtain the minimum system production cost will find in it much which is of interest.

Power Supply Economics indicates and describes principles and methods of analysis which will prove helpful in finding the most economical answer to problems which are constantly arising.

8—Handbook of Chemistry and Physics (Nineteenth Edition)

1934 pages $6.00

The Nineteenth Edition of this well-known and valuable handbook has just been published. In it have been incorporated 96 pages of new tables and 89 pages of revised and enlarged tables.

For over twenty years the *Handbook of Chemistry and Physics* has been giving a unique service to those in need of accurate tables, formulas and scientific data in a single convenient volume. This book represents many years' accumulation of necessary data for the busy scientist and engineer that is not only acceptable but highly essential in the commercial, educational and research laboratory.

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EQUIPMENT SALES
Boiler, Stoker, Pulverized Fuel

As reported by equipment manufacturers of the Department of Commerce, Bureau of the Census

Boiler Sales

Orders for 117 water-tube and h.r.t. boilers were placed in October and November

	Number	Square Feet
October, 1934	64	161,860
November, 1934	53	135,852
January to November (inclusive, 1934)	800	2,304,754
Same period, 1933	888	2,705,620

NEW ORDERS, BY KIND, PLACED IN OCT. AND NOV., 1933–1934

	Oct., 1933		Nov., 1933		Oct., 1934		Nov., 1934	
Kind	Number	Square Feet	Number	Square Feet	Number	Square Feet	Number	Square Feet
Stationary:								
Water tube	41	188,721	34	157,460	37	133,141	32	115,692
Horizontal return tubular	49	62,454	27	34,831	27	28,719	21	20,160
	90	251,175	51	192,291	64	161,860	53	135,852

Mechanical Stoker Sales

Orders for 462 stokers, Class, 4* totaling 76,060 hp were placed in October and November by 60 manufacturers

	Installed under			
	Fire-tube Boilers		Water-tube Boilers	
	No.	Horsepower	No.	Horsepower
October, 1934	230	25,817	44	19,041
November, 1934	165	20,581	23	10,621
January to November (inclusive, 1934)	1,425	179,561	440	175,684
Same period, 1933	1,122	140,292	408	147,643

* Capacity over 300 lb of coal per hr.

Pulverized Fuel Equipment Sales

Orders for 12 pulverizers with a total capacity of 32,740 lb per hr were placed in October and November

STORAGE SYSTEM

	Pulverizers				Water-tube Boilers		
	Total number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb coal per hour for contract	Number	Total sq ft steam-generating surface	Total lb steam per hour equivalent
October, 1934	..	..	..	......	..	.....	......
November, 1934	..	..	..	.....	..	.....	......
January to November (inclusive, 1934)	2	1	1	46,000	..	.....	......
Same period, 1933	6	4	2	220,000	4	109,432	1,445,000

DIRECT FIRED OR UNIT SYSTEM

	Pulverizers				Water-tube Boilers		
October, 1934	7	5	2	24,870	7	33,094	211,750
November, 1934	3	..	3	6,335	3	11,520	67,800
January to November (inclusive, 1934)	78	55	23	484,385	63	410,017	4,163,750
Same period, 1933	99	70	29	632,740	76	538,777	5,326,810
					Fire-tube Boilers		
October, 1934	..	..	..	.....	..	.....	......
November, 1934	2	..	2	1,535	2	3,000	15,600
January to November (inclusive, 1934)	2	3	9	11,765	13	15,486	111,900
Same period, 1933	7	3	14	19,450	18	27,610	170,940

ADVERTISERS
in this issue

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Old Turbine-Generators Retired

Units Nos. 5 and 6 at the Gold Street generating station of the Brooklyn Edison Company are being removed because they are no longer needed.

Unit No. 5, the second turbine unit to go into service in Brooklyn and one of the earliest turbine-generators in the country, is a Westinghouse machine originally rated at 7500 kw but later rewound and re-rated to 11,000 kw. It started operation on October 16, 1906. Unit No. 6, a 12,500-kw Allis-Chalmers machine, was installed in 1918. It replaced the original No. 6, a 5000-kw machine built by the same manufacturer, which was put in service about three months earlier than No. 5 and was the first turbine-generator in Brooklyn. Between installation and retirement No. 5 generated 450,172,000 kwhr, while the total output of No. 6 was 189,597,000 kwhr.

Gold Street is the second oldest of the existing generating stations on the Brooklyn Edison System. It started operation on May 20, 1900, about two and a half years after the opening of the Sixty-sixth Street Station, with a capacity of 3000 kw in four 750-kw engine-driven units. These first units were all taken out at the time No. 5 and the first No. 6 were installed. They were replaced between 1910 and 1917, by 9,000, 12,000, 21,000 and 30,000-kw machines, respectively. During 1921 and 1922 Nos. 1 and 2 were again replaced, this time by 25,000-kw units, to bring the total capacity of the station up to 124,500-kw, where it has remained until now.